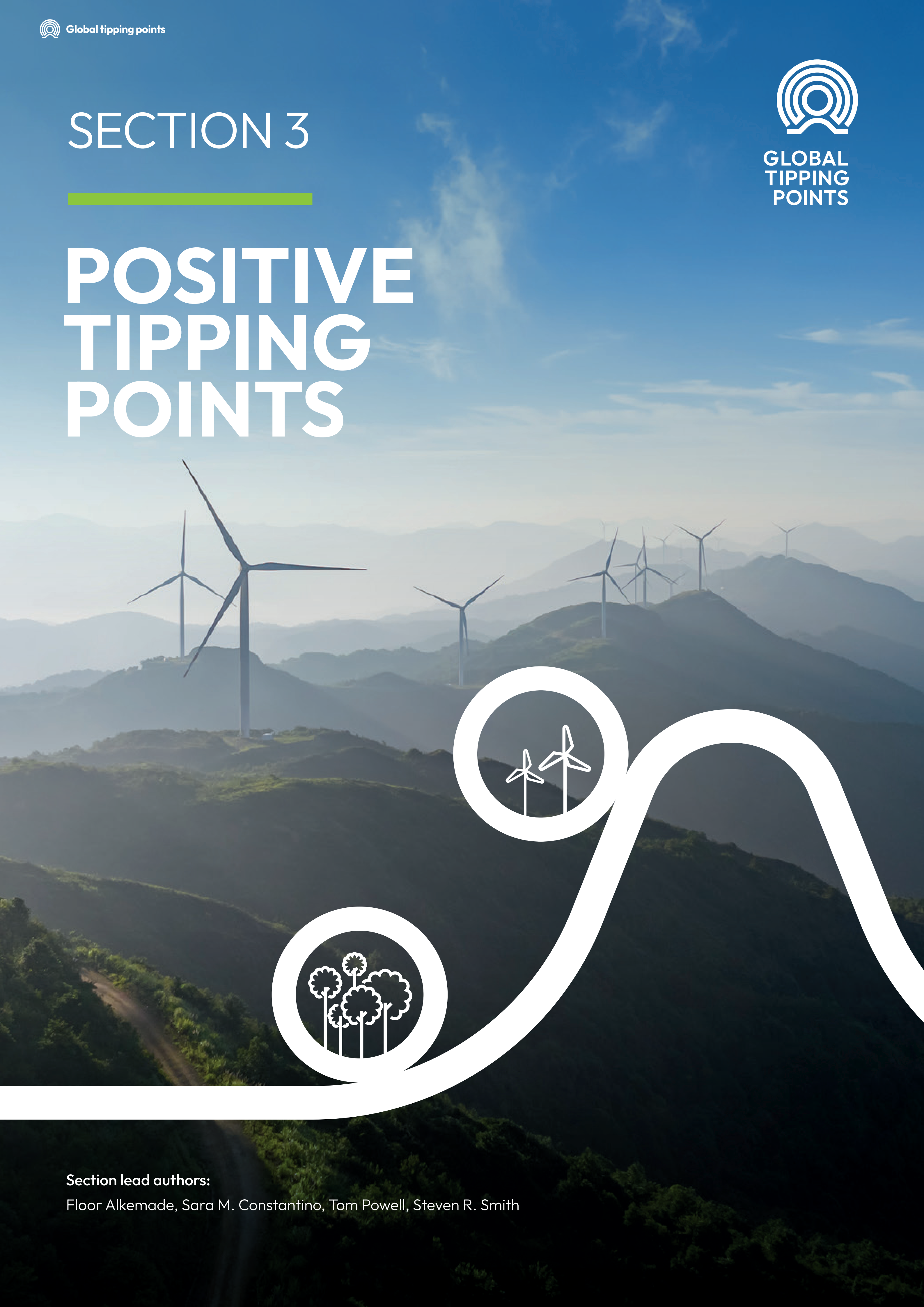

SECTION 3

POSITIVE TIPPING POINTS

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3.1 Identifying Positive Tipping Points

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Key messages

- **Positive tipping points occur when reinforcing feedbacks in a system overwhelm balancing feedbacks, triggering self-propelling change towards a more sustainable state (see Figure 3.1.1).**
- **Policymakers can accelerate decarbonisation by prioritising technologies and behaviours that have the potential to positively tip.**
- **Easily imitable behaviours in which social influence plays a strong role (e.g. active travel) and highly modular, mass producible technologies (e.g. solar panels) have the greatest potential to be positively tipped.**
- **Deliberate actions can enable positive tipping by neutralising balancing feedback, promoting reinforcing feedback and helping make a desired change the most affordable, accessible and/or attractive option.**
- **Positive tipping points have already been crossed in the adoption of solar PV and wind power globally, in the adoption of electric vehicles, battery storage and heat pumps in leading markets and there is potential for them in various applications of green hydrogen, green ammonia and alternative proteins.**
- **Early opportunity signals can reveal a loss of resilience of an incumbent system and a window of opportunity for positive tipping, but better indicators are needed to understand tipping potential and proximities to tipping points.**
- **System interactions can create opportunities for positive tipping cascades whereby tipping in one sector (e.g., battery technology) can increase the likelihood of tipping in another (e.g., renewable energy).**

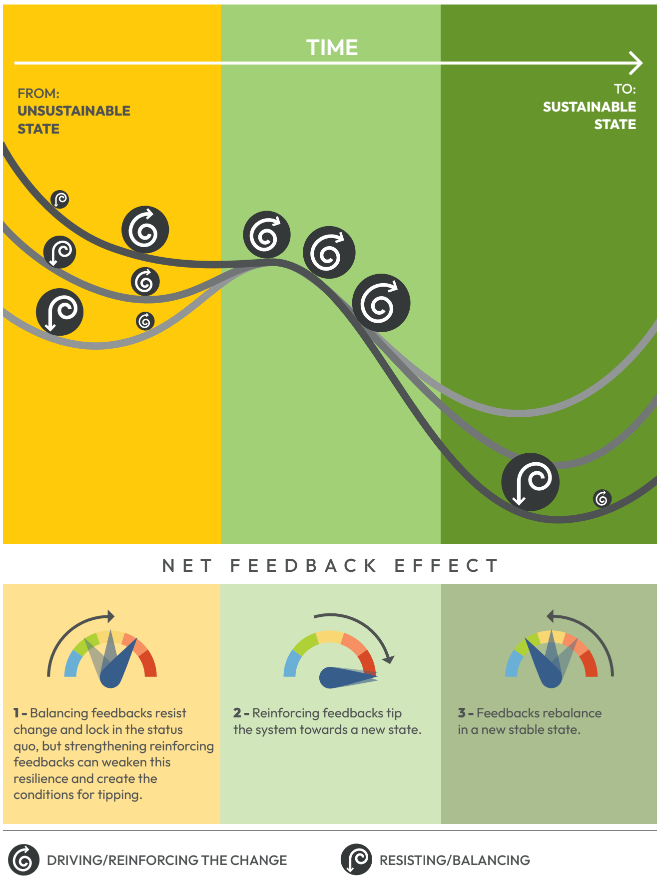

Figure 3.1.1: The ball-in-valley visual metaphor of positive tipping dynamics (Lenton et al., 2025.) Reproduced with permission.

This report has made clear that vital parts of the Earth system may already have reached tipping points, others are closer than previously thought and they are interconnected. Humanity is now entering a danger zone of civilisational risk that goes beyond local damage or regional conflicts, which could impact global society's core functioning and future. We need to respond with unprecedented urgency to eliminate the drivers of Earth system tipping points (ESTPs) - primarily fossil fuel burning and nature degradation/loss - and scale up carbon removal (primarily through nature restoration), to limit overshoot of 1.5oC. This transformation needs to happen more than five times faster than current trends for a reasonable chance of limiting warming to well below 2°C (Lenton et al., 2025). Acceleration of this kind requires positive tipping points.

A tipping point is the point beyond which self-propelling change occurs in a system, giving rise to a qualitative change to an alternative stable state. In this report, 'positive' tipping points (PTPs) refer to tipping points in human systems that have the potential to eliminate or radically reduce the drivers of ESTPs or the high and increasing costs of climate change impacts and adaptation. The alternative, desired stable state may provide a host of other benefits in terms of nature and biodiversity, human health, energy security, democracy and economic productivity within planetary boundaries.

We acknowledge that positive is a value judgement based on the collective goal of achieving a sustainable and socially just future for all. Our approach, definition and use of the term are explained in the previous Global Tipping Points Report (GTPR) (Lenton et al., 2023). We also acknowledge that not all options are equally climate or nature positive. The most sustainable option is probably to avoid using a product or service in the first place. The next best option is to shift to less harmful products or services or improve their environmental performance. For example, although some countries may have already crossed a tipping point and significantly reduced the environmental impact of car travel by replacing petrol or diesel-powered cars with electric cars, an even better option would be to avoid car travel altogether, for example in favour of active travel (e.g., walking or cycling) or public transportation powered by renewable energy (OECD, 2025).

Central to the positive tipping points approach is the imperative for transformative change to be equitable or socially just, mindful that those least responsible for creating the threat of Earth system tipping points face the greatest peril. Consideration of who is being asked to change and where and how that change will be felt, are fundamental questions for all decision-makers. The positive tipping point action agenda needs to ensure diverse perspectives and representation, with a particular emphasis on the inclusion of marginalised voices, to ensure equitable and sustainable outcomes (Pereira et al., 2025).

A positive tipping point can manifest as a rapid phase-in of a desired, sustainable innovation (idea, social practice, or technology), or as a rapid transition away from an undesired, unsustainable incumbent (Allen and Malekpour, 2023) and the two can be interdependent (Turnheim and Geels, 2012).

While current responses are grossly insufficient, there are markets and sectors currently undergoing rapid transition. Solar power is growing exponentially, doubling its installed capacity every three years (although this global growth is highly skewed towards China, which accounted for 65% of additional capacity in 2024 (IRENA, 2025)). Electric vehicle (EV) sales increased 25% globally in 2024, even more in emerging markets (particularly for two and three-wheelers (Bloomberg Electric Vehicle Outlook 2025)), as lithium-ion battery prices continue to plummet. These rapid transitions are starting to reinforce each other (Nijsse et al., 2024). A second life for used EV batteries as energy storage and vehicle-to-grid (V2G) technology, are both helping renewable electricity to solve its supply/demand balancing problem and thereby lower its cost. Ever-cheaper renewable energy elevates the economic and environmental case for electric vehicles as well as for other renewable energy users, such as the production of green hydrogen, which in turn improves the viability of green steel, as well as green ammonia for fertilisers, shipping fuel and energy storage.

Furthermore, history provides countless examples - from the invention of the electricity grid to the abolition of slavery - in which change happened slowly at first, then all at once —due to the existence of positive feedbacks causing an initially gradual change to gain momentum and become self-reinforcing after a threshold was reached (Lenton et al., 2025).

There have been significant developments since the first GTPR was published in 2023. This update largely focuses on these, many of which are technological in nature. This does not imply that shifts in social behaviours, norms, beliefs or political economies are less unimportant. It reflects the fact that much of the research, policy design and capital in this area has been invested in technologies. We do discuss some behavioural options for reducing material and energy demand in overconsuming countries, but our treatment is not comprehensive. Our intended readers are primarily senior, decision-making 'insiders', but we do not ignore the role of 'outsiders' - activists, organisers and entrepreneurs - who make low-carbon technologies and behaviours politically and economically viable over years and sometimes decades of struggle. As the great systems thinker Dona Meadows herself argued, the most powerful transformation of all would be a shift to a new worldview and policy paradigm that measured progress and prosperity primarily in terms of wellbeing - human and ecosystem health - rather than wealth and the GDP. There are faint signs of hope in this regard, even in policy circles, but unfortunately not enough to warrant further discussion here.

The first significant development is that researchers have devised a framework for identifying positive tipping points and actions to trigger them (Lenton et al., 2025). This is summarised in the rest of this chapter and chapter 3.2. In this chapter, we identify the features that make a system likely to tip and apply this to identify systems with high PTP potential. In chapter 3.2, we discuss the enabling conditions, actions and actors that are key to accelerating tipping for systems along different phases of the tipping points process.

Second, there have been significant accelerations in key sectors. The overall progress is summarised in chapter 3.3, in which we provide update reports for 11 key sector transitions. Then, in chapter 3.4, we delve deeper into tipping dynamics related to renewable power and electrification of the energy system. Finally, in chapter 3.5, we investigate tipping dynamics in the food system, land-use and nature regeneration.

3.1.1 Identifying positive tipping potential

The concept of a positive tipping point is illustrated in Figure 3.1.1. Initially, well before the tipping point, balancing feedbacks within the system maintain the initial state/status quo (the ball is firmly in the lefthand valley). The stronger these balancing feedbacks are, the more resilient the current, unsustainable system to resist change (Schilling et al 2018). At the tipping point, reinforcing feedbacks within a system overcome the balancing feedbacks and can become strong enough to support self-propelling change. Change accelerates, then eventually slows as a new, qualitatively different state is reached (the ball settles into the righthand valley). Different balancing feedbacks arise that 'lock in' or stabilise the new system state. These might include new infrastructure, such as electric vehicle (EV) charging stations), new social norms, or new institutions such as EV lobbying groups and federations that consolidate and advance the interests of the EV industry and owners.

To identify whether a system has the potential for a positive tipping point it is important to understand something about its feedbacks, including the relative strength of balancing versus reinforcing feedbacks and how they influence adoption (Lenton et al., 2025; Mascia and Mills, 2018). The most fundamental reinforcing feedback is that the more people who adopt something new, the more people they can influence to also adopt it. This is called social contagion. It could simply involve people imitating one another, but often adopters learn about what they are adopting from each other. Another key reinforcing feedback is increasing returns, which occur if adoption increases the benefits (or lowers the costs) for subsequent adopters. This can happen, for example, because learning by doing improves the performance of a technology and makes it more attractive (e.g., the range of an electric car), or economies-of-scale make it more affordable, or the rollout of complementary technologies make it more accessible (technological reinforcement).

For example, the transition from internal combustion engine vehicles (ICEVs) to electric vehicles (EVs) is characterised by learning by doing, economies of scale and technological reinforcement. The more EVs and batteries that are manufactured, the better and the cheaper they get, making EVs a more affordable and attractive option. As more drivers switch to EVs there is a greater political and commercial incentive to invest in charging stations, which makes it more convenient to make the switch. There are also social influences and changing norms that can reinforce adoption, such as seeing neighbours driving EVs.

Changes in human societies occur within social networks. To understand how and why people choose new technological solutions and adopt new norms and behaviors, we need to know how and when these solutions spread within social networks, as well as how this spread is facilitated or blocked by different social structures and actors. Modelling and empirical studies that found that tipping in social networks is possible with a range of 10-43% adoption in the population, most commonly around 25% (Everall, 2025, Centola et al., 2018). This level is influenced by factors in the population such as trust, social proximity and the structure of social networks. Beyond the tipping point, the fraction of those adopting new norms or behaviors rapidly increases (Centola 2021).

However, before positive tipping can occur, these reinforcing feedbacks must overcome the balancing feedbacks and other factors that can strongly resist change. These range from well-funded misinformation and political lobbying campaigns funded by the fossil fuel industry and libertarian think tanks, to fossil fuel subsidies and other policies, to cost and inconvenience barriers for consumers (Tindall et al., 2022; Oreskes and Conway, 2010; Dunlap and McCright, 2015). These 'forces of climate delay' offer a narrative that some segments of the population find persuasive (Lamb et al., 2020; Cherry et al., 2024; Nisbett et al., 2024; McKie, 2021). The history of the tobacco industry's attempts to subvert public health/anti-smoking campaigns from the 1950s is instructive for the climate movement's current battle against those seeking to delay climate action (Malone, 2022).

The potential for PTPs is evident in recent case studies in personal transportation and the power sector (Sharpe and Lenton, 2021; Geels and Ayoub, 2023; Hoekstra and Alkemade, 2025). For example, the Norwegian car market passed a tipping point for the uptake of electric vehicles (EVs) around 2012 (Lenton, 2025), triggering an accelerating decline in sectoral emissions. Similarly, the uptake of solar photovoltaic power worldwide is estimated to have recently passed a tipping point and is set to become the dominant source of power by 2050 (Nijsse et al., 2023).

Policy and other interventions can create the enabling or threshold conditions for tipping to occur by weakening balancing feedbacks and/or strengthening reinforcing feedbacks. These enabling conditions may include making the desired innovation (idea, behaviour, technology) the most attractive, affordable and accessible option (Meldrum et al., 2023). For example, the transition from ICEVs to BEVs in Norway included several enabling conditions for positive tipping, including financial subsidies for purchasing BEVs, preferential treatment of BEVs (e.g., access to the carpool lane (Elbil, 2024)) and global improvements in the quality and affordability of batteries.

To inform effective strategies to promote PTPs it is critical to identify where and when PTPs are possible. This requires (1) defining the system of interest, (2) assessing its tipping potential and, if there is tipping potential, (3) assessing its current state (e.g. level of adoption).

Once this is understood, it is important to identify how to trigger PTPs. This involves identifying (4) key system leverage points and enabling conditions and (5) the sequence of actions needed to trigger the PTP. These steps are described in the flow diagram in Figure 3.1.2.

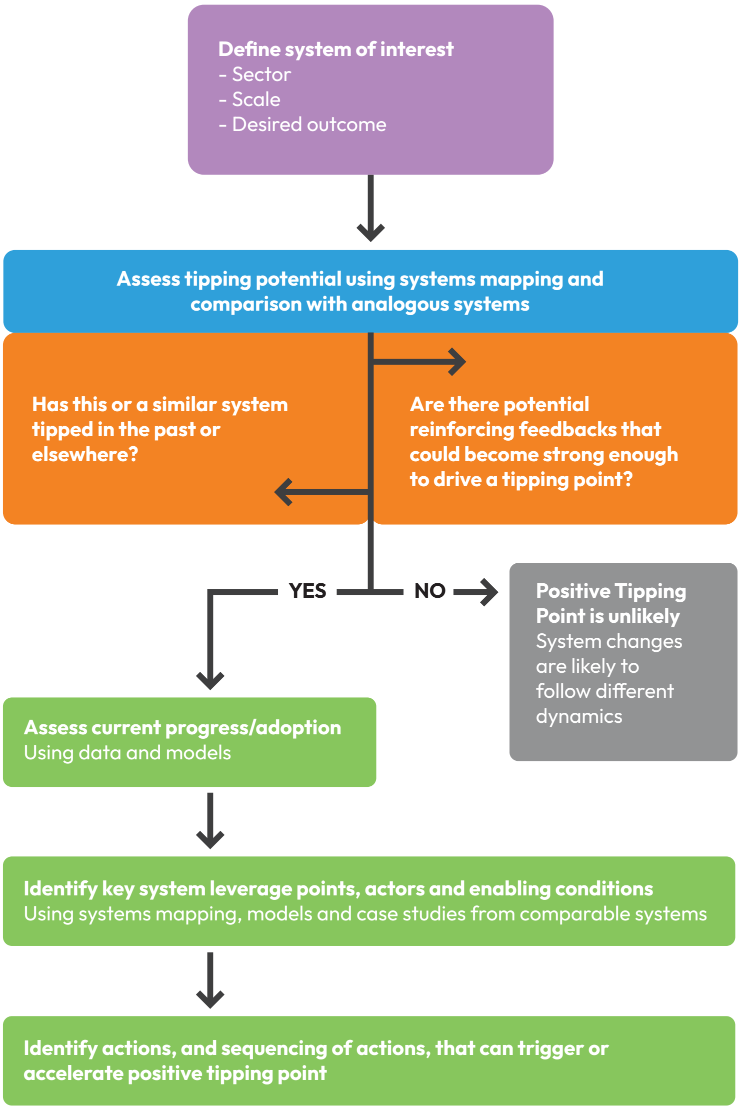

Figure 3.1.2: Simplified framework for identifying systems with potential for PTPs and for acting on those systems to bring about a transition to an alternative state (adapted from Lenton et al., 2025).

3.1.2 Defining the system of interest: actors and conflicting goals

The first step in understanding whether a system is likely to tip is to define the system of interest. This might be a specific sector, or it might be limited to a specific geographic area. For example, we might consider the global energy system or the UK car market as the system of interest.

Many different actors (e.g., policymakers, business leaders, community organisers) and actions can play a role in creating the conditions for positive tipping dynamics. For example, in the UK transport sector, policymakers at the national scale have brought in zero emission vehicle mandates for new cars by 2035; city level authorities have introduced low emission zones (LEZs) or clean air zones (CEZs) to tackle air pollution; community organisations have campaigned for pedestrianised streets and bicycle lanes; and businesses are investing in new research and manufacturing facilities for EVs, batteries and renewable power generation (Lenton et al., 2025).

However, different actors often have different goals—for example, rapid decarbonisation or social equality and wellbeing—and different visions for how to achieve those goals (e.g. market based approaches vs. regulation), or oppose them. They may also prioritise near-term changes over longer-term and harder to achieve changes. In the example of the UK transport sector, the ultimate goal might be to reduce car use altogether and to increase walking and biking, while the near-term goal may be to replace ICEVs with EVs (Behrendt, 2018).

Successful tipping dynamics depend, in part, on the irreversibility or resilience of the new desirable system. Hence, it is important to ensure public acceptance of tipping interventions to ensure they can withstand backlash (Pereira et al, 2024; EEA, 2024). Transitions, even as they meet important goals such as decarbonisation of transport, often create new winners and losers. Sometimes these groups are easy to identify upfront and those that become relatively worse off can be supported in the transition (e.g., reskilling workers in the oil and gas industry (Pollin, 2023), or compensating farmers for land-use changes (Kuhmonen, 2022)) to reduce resistance to change.

3.1.3 Assessing tipping potential

Once the system has been defined, one can assess its potential for a positive tipping point by examining similar systems, in the past or in other parts of the world, as well as mapping characteristics of the system (e.g. potential for reinforcing feedbacks). For example, the UK car market today is at a similar point in terms of EV market share to the Norwegian car market circa 2015. Norway has since undergone a rapid and near-complete transition to EVs. However, there are notable differences, including that Norway has no car manufacturers and generates almost all of its electricity using clean hydropower.

We introduced above some of the key reinforcing and balancing feedbacks that determine a system's tipping potential. Below we provide a more comprehensive list. The highest positive tipping potential occurs in systems where the relative strength of reinforcing feedbacks is high and balancing feedbacks can be weakened or neutralised.

First, reinforcing feedbacks include social contagion, increasing returns to adoption, investment pathways, positive political and policy feedbacks and discourses of positive climate action.

Social contagion describes a situation where adopters imitate and learn from one another (Rogers, 1962; Zeppini et al., 2014; Lenton et al., 2022). The adoption of a new technology, social norm, or behaviour makes it more likely that others will adopt it due to the power of imitation, conformity and social learning, the most studied example being the clustered adoption of neighbourhood rooftop solar PVs (Granovetter, 1978; Centola et al., 2018 Serra-Coch et al, 2023; Graziano & Gillingham 2014;).

Increasing returns to adoption describes systems where adoption increases the benefits (or lowers the costs) to subsequent adopters through increased accessibility of the innovation, or because of economies of scale or learning by doing that decrease prices. With **economies of scale** production rates increase faster than production costs, which lowers unit costs, which then increases demand, increasing the rate of production and so on. The more of something you produce, the cheaper it gets. Similarly, **economies of networks** occur when the value of a product or service increases the more people use it, for example a social media platform or an electric vehicle recharging network. **Technology reinforcement**: the more an innovation is used, the more additional technologies and practices emerge to complement it and make it even more valued/useful (Lenton et al., 2022) are a specific form of network externalities. **Learning by doing**: workers and firms continually learn from experience, improve processes and make efficiencies. This reduces costs by a fixed percentage for every doubling of production (according to Wright's Law), the more times you make something the better you get at making it (Yelle, 1979; Wright, 1936). Learning rates and cost reduction speeds are higher for modular technologies that are easier to mass produce (e.g., solar PVs, batteries and electric vehicles) and lower for technologies with higher degrees of design complexity and customisation (e.g., nuclear power plants, carbon capture and storage, or building retrofits) (Wilson et al., 2020; Malhotra and Schmidt, 2020).

Investment pathways - patterns of capital allocation that enable sustained financial flows into emerging low-carbon technologies and sectors - can help overcome financial lock-ins, reduce perceived risks and build market confidence, particularly in underinvested regions or markets. Early and well-aligned investments create positive feedback loops that reinforce other enabling conditions and accelerate transitions (Ameli et al 2025).

Positive political and policy feedbacks: the growth of stable, healthier, higher paying jobs in renewable energy, electrification, batteries, heat pumps and sustainable agriculture and the health benefits of cleaner air and waterways positively reinforces public and corporate support for more radical action (Lockwood et al., 2015). Related, positive policy feedback occurs when the falling costs of clean technologies or previous investments enable stronger public investment and policies for technology deployment and infrastructure (Jordan and Moore, 2020).

Discourses of climate action: Positive, hopeful stories of transformation, both real and imaginary, reinforce the belief that change at the required speed and scale is possible. Positive experiences and accounts of experimental places, projects and policies that prefigure the sustainable future we wish to create (e.g., Transition Towns) are highly motivational and can become self-propelling: "If it can happen 'there', why not 'here'" (Potential Energy Coalition, 2023; Rapid Transition Alliance, 2021; Raekstad and Gradin, 2020).

Balancing feedbacks and other factors that resist systemic change include lock-in, political and policy resistance and negative climate discourses.

Lock-in can take the form of institutional, infrastructural, technological, or psychosocial inertias in which habits, social norms, customs and beliefs are resistant to change. These inertias are reinforced by institutional structures, such as investment pathways that direct financial resources into existing systems and infrastructures, creating long-term commitments that constrain the adoption of alternative trajectories, or education and human resources structures such as curricula and professional standards that are designed for incumbent technologies (William and Bonvillian 2013).

Political resistance: climate change deniers and climate action delayers motivated by self-interest, libertarian ideology or a strategic interest in stoking populist, divisive narratives can build political coalitions to oppose change. These narratives are often centred on grounds of economic cost and loss of personal freedom/government interference (Coan et al., 2021; Lamb et al., 2020).

Policy resistance: policies that obstruct or resist clean innovation and change, such as the continuation of fossil fuel subsidies advocated by powerful incumbent lobbyists from the fossil fuel industry and weakening of policies due to concerns over financial costs and backlash from affected industries, groups or the general public (Jordan and Moore, 2020).

Discourses of denial/delay: the percolation and diffusion of mis/disinformation and counter-narratives to climate action are most effective where right-leaning (divisive, populist) political parties and media networks are influential (Earle, 2021; Lamb et al., 2020; Dunlap and McCright, 2015; Oreskes and Conway, 2014).

3.1.4 Assessing Progress in Systems with PTP Potential

Systems with high PTP potential can be at different parts of the tipping trajectory, which is often characterised by an S-curve of technology diffusion: slow at first, then rapidly rising, before flattening out again as market saturation or majority is reached. The shape of the S-curve is influenced by feedback loops. As reinforcing feedbacks take hold, the rate of adoption accelerates. The adoption rate slows again as balancing feedbacks establish a new system stability.

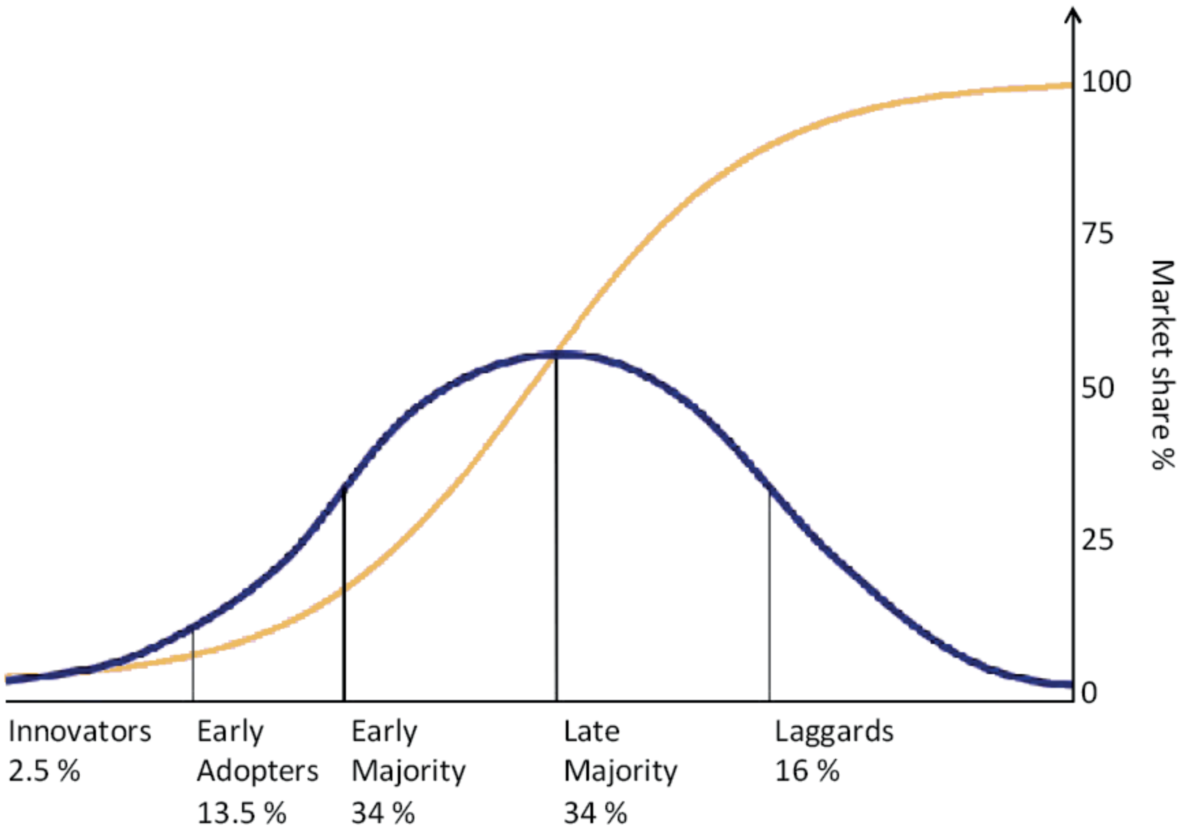

Figure 3.1.3: S-Curve of Innovation Diffusion in Systems with PTP Potential.

The process of an S-curve is context specific, but researchers have identified common patterns and characteristics along different parts of the S-curve, with generalisable lessons. These studies often break down the S-curve into phases (Rotmans et al. 2001, Victor et al. 2019; Systemiq 2021; EEIST 2021; Henderson and Sen 2021). Here, we consider the S-curve in three phases of the tipping points process, in each of which the system dynamics, leverage and roles of key actors may differ:

- **Phase 1. Emergence**
  - Visionaries recognise a problem or opportunity and conceptualise a better way to do things. Innovators move the concept from the laboratory, models and sketches to working prototypes or pilots.
- **Phase 2. Acceleration**
  - Diffusion in niche markets: Early adopters form niche markets, connecting supply and demand. Performance increases and costs decline but the innovation remains at a premium and is not widely available.
  - Diffusion in mass markets: The innovation reaches the mass market as it outperforms incumbents in costs and performance. This is the steep part of the S-curve.
- **Phase 3. Stabilisation**
  - Growth slows as the innovation reaches market saturation. The innovation may be transferred to new markets or help catalyse further innovations and forms the basis of a reconfiguration of socio-economic systems.

Understanding where a system sits on this curve is crucial to identifying the key leverage points to accelerate adoption—we return to this in chapter 3.2.

Trends in key indicators such as changes in the market share of sustainable technologies, price and performance metrics, capital investment, or social media data can help identify where on the S-curve a system is. Data can also provide insights into the effects of policies or other interventions, the likelihood that the system will progress to the next phase of the tipping points process and potential barriers to progress.

Analysis of longitudinal data may provide early indicators of tipping opportunities. Just as early warning indicators—such as critical slowing down or the rate at which a system recovers from shocks or perturbations—can signal the approach of an ESTP, **early opportunity indicators** may signal the proximity to a PTP. These indicators detect the loss of resilience of the incumbent state following a shock to the system (e.g. price shocks). If the system recovers rapidly, the incumbent state is likely resilient. If it is slow to recover, this may signal growing engagement with, investment in or market share of sustainable alternatives (see Box 3.1.1). For example, economic or sociopolitical pressures and weakening performance or legitimacy of an incumbent technology (e.g. ICEVs) or behavior can lead to a growing exploration of alternatives (e.g. EVs).

Loss of resilience alone does not guarantee that tipping will occur but the nature of fluctuations in the system can give clues as to whether a tipping point may be approaching (Kuehn, 2011; Bury et al., 2021). Further, it can point to windows of opportunity or critical periods for action by key stakeholders (see chapter 3.2).

Box 3.1.1: Detecting early opportunity signals for tipping in battery electric vehicle (BEV) adoption

Changes over time in statistical properties of key indicators such as market share can indicate changes in resilience through 'critical slowing down', in which a system becomes more sensitive to perturbations and takes longer to recover from shocks as it loses resilience.

For example, in the current market where vehicles powered by internal combustion engines (ICEVs) are incumbents and have the majority of market share in most national jurisdictions, market share of ICEVs vs BEVs should become more susceptible to fluctuations in demand and take longer to recover from shocks as the incumbency of ICEVs becomes less resilient under pressure of competition from BEVs.

Starting in 2020 market share of ICEVs in Chinese and European markets showed critical slowing down prior to abrupt declines and corresponding rapid increase of market share of BEV and hybrid vehicles (Mercure et al 2024, GTPR 2023). In the UK, the share of BEVs in viewing figures for online advertising of second hand vehicles shows a similar statistical trend, with increasing spikes of interest over time which are also becoming more persistent (Boulton et al 2025).

3.1.5 System Interactions and Tipping Cascades

It is important to keep in mind that systems do not exist in isolation. Their interactions mean that crossing tipping point thresholds in one system can lead to tipping in others, potentially causing a domino or cascading effect (Sharpe and Lenton, 2021; Eker et al., 2024). For example, the self-reinforcing economies of scale and learning by doing that have dramatically improved the cost and performance of batteries influence the tipping point for renewable power generation by helping to solve the supply/demand balancing problem. The decline in price of renewable energy in turn brings forward the tipping point in electric vehicle sales. It also brings forward the tipping point for producing affordable green hydrogen, which in turn improves the economic case for green steel and for green ammonia for fertilisers and shipping fuel (Lenton et al., 2023). In contrast to negative tipping cascades in Earth systems, positive tipping cascades in social systems offer the potential to generate rapid and broad beneficial change.

At the same time, this interdependence between systems means that efforts to reach a PTP in one system may be dampened by feedbacks in another system. An example are rebound effects where incentives to invest in energy efficiency are reduced when abundant affordable renewable energy is available. Another example is the temporary constraint that energy related grid congestion places on further demand electrification or household level renewables.

3.2 Acting on positive tipping points

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Key Messages:

Policy design needs to match the phase of a positive tipping process

- Effective sequencing of interventions is important to activate positive tipping points. Different opportunities exist to overcome barriers and enable scaling at different phases of an S-curve of adoption. Effective policy design needs to match the system's tipping phase.
- Policy mixes need to be appropriate to the scale, context, sector, actor, and phase of transition, to effectively catalyse and facilitate positive tipping dynamics (see Figure 3.2.4).

Positive tipping points need to be well governed to ensure a rapid and just transition

- Governance can create the enabling conditions for positive tipping, including easing access to finance, providing the necessary infrastructure to support rapid deployment, and cultivating sufficient stakeholder engagement and public support for policies to be approved and implemented.
- Rapid transition benefits from governance that is collaborative, localised and tailored to what communities say they want through participatory methods.
- Governments need to be aware of the potential for unintended consequences from positive tipping points including financial and political instability, stranded assets (including human assets) and perceived (in)justice of the transition.

Cross-cutting factors can support positive tipping points

- Patterns of capital allocation that enable sustained financial flows into emerging low-carbon technologies and sectors can help overcome lock-ins, reduce perceived risk and build market confidence, particularly in underinvested regions and markets.
- Digitalisation and AI have the potential to accelerate positive tipping points by managing complex systems from renewable energy smart grids and transportation systems to social deliberation processes.
- Climate communications in the format of film, journalism, performance art and other media can be instrumental in generating the political momentum for positive change, particularly when connected to targeted policy advocacy and trusted messengers.

Coordination and coalitions can catalyse positive tipping points

- Coordinated cross-sectoral action at 'super-leverage points' can unleash positive tipping cascades. Coordinated mandates across interacting sectors (e.g. power, transport and heating) can bring forward tipping in all.
- Coherent, committed, ambitious coalitions can challenge incumbencies and catalyse positive tipping towards majority adoption of social and technological innovations.

3.2.1 Introduction

Identifying conditions and actions to bring about positive tipping points is key to decarbonising our society at the scale and pace needed to reduce the impacts of climate change and avoid ESTPs (Otto et al., 2020; Lenton et al., 2023; Ong et al., 2025; Meldrum et al., 2023). Creating the conditions for PTPs requires strengthening enabling conditions that promote desirable self-reinforcing (positive) feedbacks, while overcoming balancing (negative) forces. Recent efforts have thus focused on identifying these enabling conditions and 'leverage points' or 'sensitive intervention points' — points in a system where small interventions can create significant and self-reinforcing change (Mealy et al, 2023; Farmer et al 2019; Meadows, 2008)—and the actions that can be taken to increase the likelihood of crossing PTPs.

In this chapter, we discuss some of these enabling factors and leverage points, illustrated with examples from specific key systems for decarbonisation, organised as follows:

- Overview of the types of measures that can be taken to enable positive (reinforcing) feedbacks and overcome negative (balancing) feedbacks (see 3.2.2).
- Consideration of how the strength, sequencing, and combination of measures can accelerate change within and across systems (see 3.2.3).
- Examination of how a domino effect of positive tipping cascades can accelerate change across sectors, demonstrated in a model of four interacting sectors – renewable power, residential heating, light road transport (cars) and heavy road transport (trucks) (see 3.2.4).
- Discussion of some key social and political considerations to enable positive tipping (see 3.2.5).
- Discussion on the importance of coalition-building to facilitate positive tipping (see 3.2.6).

This chapter aims to be useful to policymakers, financial investors, insurers, business leaders, media organisations and civil society organisers, all of whom have a vital role to play in accelerating decarbonisation and managing potential risks and unintended consequences.

3.2.2 Enabling positive feedbacks and overcoming balancing feedbacks

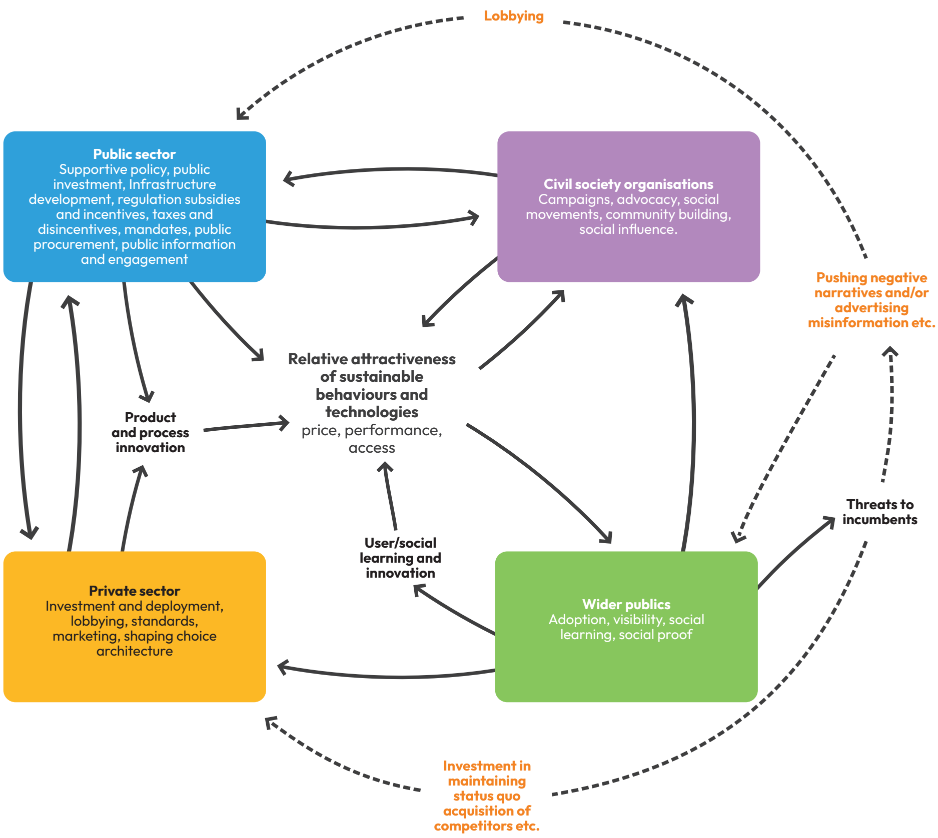

Figure 3.2.1: Generic diagram of the reinforcing feedbacks among the public and private sectors, civil society organisations, and the wider publics of adopters who influence the relative attractiveness and prevalence of sustainable technologies and practices. Colours correspond to different actor groups. Also shown are some of the balancing feedbacks that might emerge in response to the growing adoption of a new technology or practice. Solid lines indicate positive causal relationships, and dotted lines indicate negative relationships.

How different actors can enable positive feedback

Enabling conditions improve the relative attractiveness, accessibility and/or affordability (discussed in greater detail in Chapter 3.1) of a desired innovation, increasing its likelihood of adoption (Figure 3.2.1). Creating these enabling conditions, while overcoming the balancing forces maintaining the status quo, often depends on specific, deliberate and to some extent coordinated measures by actors from multiple sectors of society. For example, a transition to a low-carbon society requires lowering the costs of clean technology, incentivising private investment in clean energy, building clean energy infrastructure, encouraging low-carbon lifestyles and norms, and building social and political support for rapid change, all of which have potential for reinforcing and cascading feedbacks (Sovacool et al., 2025; Willis, Curato and Smith, 2022; Boswell, Dean and Smith, 2022). This "all hands on deck" perspective emphasises that: the conditions for change can start at many points in a system, with different actors having agency to bring about systemic change.

There are many ways that positive, self-reinforcing feedbacks can emerge—and that balancing forces can be overcome. For example, bottom-up demand-side pressures—driven by innovators and entrepreneurs or new needs or knowledge that lead to changes in the priorities of the public—can create opportunities for social or political change while putting pressure on incumbents to adapt. Bottom-up pressures may be especially important in contexts with strong incumbent industries and governments resistant to change.

At the same time, top-down actions by governments or businesses can also incentivise shifts away from incumbent technologies and practices towards low-carbon ones. Public policy can be critical to create the conditions for private capital investments in new industries when there are powerful incumbents, high costs to entry, and technological, political or market risks or uncertainties. Between these two ends, there are meso-level forces, such as organised civil society groups (e.g. unions, environmental groups, media) that can also be critical for seeding and supporting change.

Importantly, bottom-up and top-down forces can reinforce each other. For example, the Cool Biz campaign initiated by the Japanese Ministry of the Environment in 2005 introduced a lighter and cooler summer dress code. At the same time, it raised office air conditioner thermostats to 28°C. The combination of these two measures saved energy and lowered CO^2 emissions. This approach has since been adopted by the South Korean Ministry of Environment, the British Trades Union Congress, and the United Nations, demonstrating how successful pilots can spread through social learning.

Below, we describe some of the measures that the different types of actors shown in Figure 3.2.1 can take to create enabling conditions for PTPs. In Box 3.2.1, we describe these actions in the concrete case of UK EV adoption.

Public sector

The **public sector** can create **supportive policy** environments to rapidly increase supply and demand for low-carbon technologies and weaken the dominance of incumbent technologies, practices and norms.

Supportive environments start with **agenda setting**—the process by which some issues gain political traction while others fade—which is influenced by civil society organisations, the public, and the private sector, among others (Kingdon, 1995). **Policy windows**, created by **focusing events** such as crises (e.g. extreme weather, pandemics, financial crisis), political shifts, or other factors, can create opportunities for policy entrepreneurs to overcome institutional frictions and introduce new items onto the agenda (Giordono et al., 2020). Institutions have balancing feedbacks that sustain the status quo (e.g. fragmentation, veto power). Focusing events can change how policies are perceived and, in some cases, lead to rapid and punctuated policy change that overcomes institutional friction (Baumgartner and Jones, 1993).

If the issue rises to the government agenda, governments can create positive feedbacks and overcome balancing feedbacks through the use of different combinations of policy instruments such as **regulation** and **mandates**, **taxes** and **subsidies**, **public finance** and **direct investment, public procurement** and **guarantees**, **infrastructure** development, **public education** and **information provision**, ultimately shaping the relative strength or prevalence of new and incumbent industries, technologies and practices. Different policy instruments are critical at different stages along the innovation and adoption curve.

The **policy feedback** literature describes how the direct effects of policies can create feedbacks from the public and concentrated interest groups. **Credible** climate policies that deliver **tangible** and **short-run** benefits to industries and people that are **traceable** to the policy can create new interest groups and constituencies that support the policy (e.g. through voting or lobbying). Recent work suggests that **sequencing policies** so that benefits are realised early and often can increase subsequent support for more ambitious climate policy (Montfort et al., 2023). In contrast, starting with ambitious and broad policies right away can result in the repeal or discontinuation of a policy (Sewerin et al., 2023). For example, taxes on carbon emissions have been historically challenging to pass. Many governments instead adopted green industrial policies, thereby mobilising private capital and creating new 'green' constituencies and coalitions (Meckling 2021; Meckling et al., 2015). To the extent that this policy feedback is successful, it could ease the path for future carbon taxes.

Governments can use **public finance** or direct investment to support research & development into high risk technologies or public goods; develop **public-private partnerships** and introduce **tax credits** to reduce the cost of capital and incentivise private investment in low-carbon technologies and sectors. How policies are '**packaged**' or combined matters, and supply-side policies are more likely to create positive feedbacks when coupled with policies that strengthen demand for new technologies and practices. For example, building supportive **infrastructure** (e.g. public transit systems, bike lanes) and using **mandates**, **regulation** and **standards**, **public procurement, public education** (including correcting misinformation), **nudges** (e.g. defaults) and **consumer subsidies** create demand for low-carbon products and technologies. At the same time, governments can introduce **regulation** or **taxes** to dissuade investment in or use of incumbent fossil fuel-based technologies.

Policy instruments differ in terms of their sociopolitical **feasibility**, **impact**, **costs**, **efficiency, speed, distributional** and **equity** implications. Governance thus needs to be collaborative and tailored to the preferences of communities through participatory methods to avoid backlash (British Academy, 2025).

Private sector businesses

Private sector businesses play a key role in creating positive feedbacks to accelerate low-carbon transitions. Recent work suggests that climate governance can function like a conveyor belt that starts with voluntary pledges by companies and other non-governmental actors that eventually lead to standardisation and eventually mandatory regulation (Hale, 2018). In this sense, action by businesses can lead climate policy, while allowing for early experimentation and demonstrations of feasibility that may reduce political resistance.

As sellers, businesses can pursue **cost reduction** and **quality improvement** of their products, in turn increasing the affordability, attractiveness, and availability of their products to downstream buyers or consumers (Deloitte & RMI 2022). They can further shape demand through marketing tactics, including behavioural nudges and using influencers to adopt and promote their products (Thaler & Sunstein 2008). As buyers, businesses can have large impacts on upstream markets. Buyers' coalitions, also known as buyers alliances, are increasingly common in the clean technology space (e.g., CEBA, SABA, Sustainable Steel Buyers Platform). These coalitions unlock early-stage market growth by aggregating the demand of multiple corporate buyers. This creates a reliable source of demand, thus reducing their market risk, critical in early stages of product development, while allowing buyers to leverage their collective buying power to negotiate favorable rates (RMI 2024).

Businesses can also shape the policy environment (UN Global Compact, We Mean Business, and WRI, 2018) and public narratives, and the financial sector can shape access to capital across systems (see 3.2.2.3 on cross-cutting influences). This can be done directly through **lobbying**, **campaign finance**, and **participation in climate meetings** and other official modes of policy engagement; or indirectly, through **white papers**, **voluntary targets** and commitments (e.g., America is All In), **open letters** (e.g., BlackRock letter on stakeholder capitalism), and other mechanisms that influence public perceptions and priorities and political actions.

Whether these measures create the enabling conditions for PTPs depends on market and product characteristics—in particular, whether they are characterised by economies of scale or learning-by-doing dynamics—as described in chapter 3.1. Additionally, the PTP potential of these measures can depend critically on some of the public sector actions described above. For example, early investment and demand creation by governments can help the private sector overcome large initial fixed costs or risks.

Civil society organisations

Civil society organisations and **social movements** can accelerate the low-carbon transition through various measures—from **community-building** to **climate litigation** (see 3.2.2.3 on cross-cutting influences)—that mobilise groups for shared action (Ganz, 2024; Han, 2014). As illustrated using the pilot study to promote sustainable eating habits in Brondby, Copenhagen (Box 3.2.2. PTP theory operationalised at the local scale), a whole systems approach to PTPs begins with identifying, recruiting and developing adaptive leadership, building community around that leadership, and creating a strong and coordinated learning environment across sectors (Ganz, 2010). In seeking to expand its influence on policy, movements and social innovators need to go beyond local, grassroots, and peripheral networks and actively cultivate political "insiders", developing relationships with policymakers and other influential actors (Piggot, 2017; Newell, 2005).

Cross-cutting factors like the **media environment** in which people are embedded shape the beliefs and behaviours of individuals and communities across societal roles (see section on broader publics, below). Persuasive information campaigns can be directed either in support of decarbonisation and more sustainable behaviours or, as in the case of misinformation campaigns, in opposition to climate action. Due to their reach, media campaigns and narratives can create rapid changes in public beliefs, norms and behaviors.

Change agents, social entrepreneurs, and **innovators** can influence innovation diffusion by creating **social movements**, shaping **policy**, or affecting **markets** by encouraging **early adoption** of new technologies. They differ from the broader public in that they are often those who are less risk averse, have more resources, a strong commitment to a cause, and less tendency to conform and so are willing to go against existing social norms (Mittal et al., 2024). Civil society organisations can work with these opinion leaders to proactively shape norms, beliefs, and behaviors—by increasing the acceptability, legitimacy, and attractiveness associated with these outcomes.

Civil society - wider publics

Civil society - wider publics can also create or reinforce the enabling conditions for PTPs in low-carbon technologies and practices through their roles as consumers, investors, citizens, members of organisations, and role models (Nielsen et al. 2021; Hampton & Whitmarsh 2024; Caggiano et al. 2024). For example, consumers influence the private sector through **purchases** and **boycotts**, **shareholder activism**, and **financial** decisions; citizens can shape political and policy outcomes through **voting**, **advocacy**, or participation in **social movements**; and individuals exert **social influence** on their families, peers, and colleagues through the social networks and organisations they are a part of. Social influence can lead to non-linear increases in the adoption of new technologies and shifts in beliefs and opinions (Constantino et al. 2022).

Early adopters of new low-carbon technologies and practices—the adopters that follow the entrepreneurs and innovators described in the previous section—can have direct effects on emissions, but also widespread indirect effects through their influence on others. They often have the social and material resources to engage with new technologies and practices early on, and to withstand associated risks (Rogers 2003). For example, adoption of electric vehicles or rooftop solar was initially costly, risky and uncertain until costs dropped and the market share — and supporting services (e.g. charging stations) — increased. Early adoption increases the perceived **attractiveness** or **appropriateness** of new or alternative behaviours, technologies or beliefs by increasing their **visibility** and creating early **social proof** that they are viable or desirable, which is especially important for new, unknown or costly technologies. They can also signal the **direction a norm** is headed (“trending” or “dynamic” norms). Early adopters of rooftop solar have been shown to predict subsequent adoption among their neighbors (Graziano and Gillingham, 2015; Gillingham and Bollinger, 2021).

Visibility and social proof can be strategically increased through events like solar parties that bring together adopters with peers who have not adopted (Hecher et al., 2025; Hecher et al., in prep.) or the introduction of artefacts that render visible certain behaviours or beliefs (e.g. “I voted” stickers, yard signs, symbols on clothing). Early adoption can also be **strategically seeded** through targeted interventions and policies (e.g. targeted spillovers or education campaigns) to increase the likelihood of spillovers to others (Nyborg et al., 2016). Indeed, research on political movements, technology adoption, and norm change finds that there is a **critical mass** of adoption, ranging from 10% to 43% of a population, after which the fraction of adopters can increase rapidly (Everall 2025; Granovetter 1978; Chenoweth and Stephan 2011; Rogers 2003; though see Efferson et al., 2020).

Different **network configurations** can facilitate or impede the spread of new norms and behaviors. For example, ‘small world’ networks or ‘tiny publics’ may be effective configurations for the establishment of new social norms (Fine 2012). Rooftop solar has been shown to spread according to a **complex contagion process**: multiple points of social proof are required before an individual adopts (Centola 2021; Constantino et al. 2022). Where an individual sits in a network — and characteristics of the behaviour and how it spreads — contribute to their **agency** to influence others.

Growing public adoption of a new technology or practice can increase its perceived attractiveness, legitimacy and acceptability, while also creating a dedicated constituency that reinforces the new behaviour or technology through the various roles described above. When governments are **responsive** and **legitimate**, acting on broad public preferences, rather than on the interests of a few (Gilens 2024), changes in public opinion can, in turn, shape political and policy outcomes. Additionally, the same social forces — social learning, conformity etc. — that create rapid initial change also sustain new social norms once they emerge and take root (Young 2024).

Box 3.2.1: Policy sequencing to enable a PTP in UK electric vehicle adoption.

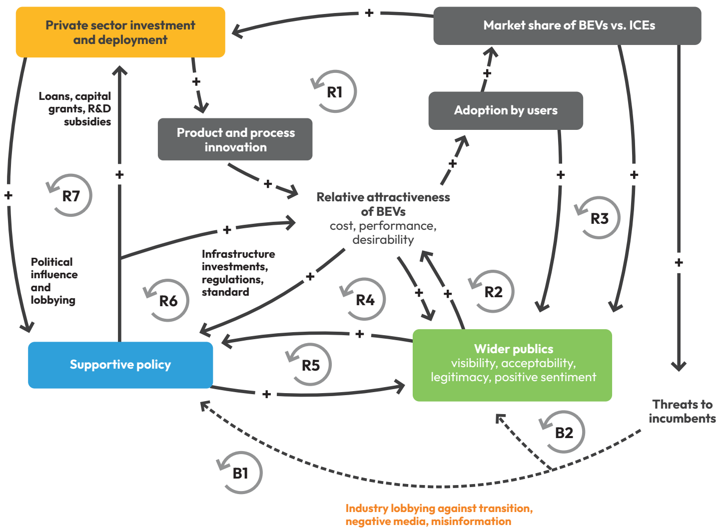

Figure 3.2.2: Systems map of key reinforcing (R) and balancing (B) feedback loops in the UK light-duty road transport system. Reproduced from Adapted from Geels and Ayoub, 2023, and Lenton et al., 2025.

The UK light-duty road transport system exhibits reinforcing feedbacks (R) that are strong enough to overwhelm balancing feedbacks (B), supporting self-propelling change from ICEVs to BEVs.

Reinforcing feedbacks include:

- Increasing returns to adoption due to economies of scale, learning-by-doing, and technological reinforcement (R1).
- Diffusion of information and social norms that support BEVs (R2, R3).
- Policy feedbacks (e.g. zero emission vehicle mandates) and political momentum that is reinforced by co-benefits such as public health (R4-R7).

Balancing feedbacks that reinforce the status quo include:

- Industry lobbying against policies that support BEVs or constrain ICEs (B1).
- Misinformation campaigns supported by media, politicians and influencers (B2).

The UK electric vehicle fleet has expanded rapidly in recent years and is now firmly in the accelerating phase of the tipping process (see Figure 3.2.4), the market share for new BEV sales reached almost 20% in 2024 when the total cost of ownership for a mid-sized BEV became comparable with an ICEV. Multiple analyses and forecasts indicate that the upfront cost of EVs will reach parity with ICEVs by 2026 for mid-sized vehicles and around 2028 for luxury models. This shift is driven by falling battery costs, which are predicted to fall below $100 per kWh threshold by 2026, making EVs as cheap to manufacture as their petrol-powered counterparts.

Public sector: effective advocacy coalitions resulted in the 2008 Climate Change Act and climate-related transport policy, which increased new investment, R&D, coordination between automakers, policymakers and research organisations, recharging infrastructure, and purchasing incentives. Policymaking also experienced a tipping point in 2015 as governments realised the need for an integrated transport decarbonisation and industrial strategy.

Policies became more focussed on supporting manufacturing, supply chains, mass EV adoption and rapid charging infrastructure. The 2017 Clean Growth Strategy led to new capital grants and subsidies for automakers and battery makers to build manufacturing plants. At the same time, new EU car emissions regulations required automakers to at least part-electrify new cars by 2020. Despite some success from these policy stimuli in terms of new car and battery plants, the UK's industrial and policy environment and Brexit-related trade complications have led some auto and battery makers to close or avoid UK-based operations in favour of continental European and Asian production (Geels and Ayoub, 2023). Better infrastructure promotes EV adoption (Buhmann and Criado, 2023) but almost half (47%) of UK consumers believe there are too few few charging points (Autotrader Consumer Research, May 2023).

Private Sector: Automakers initially made defensive R&D investments in the 2000s in response to successful first movers (e.g. the Toyota Prius) and early climate-related policy and public pressures. Over the course of the 2010s (particularly from 2015), increasing demand (especially from international markets such as China), policy pressures, and the aftermath of the 'dieselgate' scandal led to more concerted efforts by automakers to improve battery capacity, size efficiency, range (average range grew 75% from 2015 - 2023) and charging speed (increased from 50kW in early 2010s to 350 kW in 2024 (IEA, 2024)). This increased the attractiveness and reduced the cost of EVs through economies of scale and learning-by-doing (Geels and Ayoub, 2023).

Overcoming balancing feedbacks that sustain the status-quo

To positively tip adoption of a desired technology or practice, it may be important to not only create enabling conditions for positive feedbacks but also to remove or weaken system structures that strengthen incumbents and maintain the status-quo. Balancing effects can arise from path dependencies — for example, large infrastructural systems such as roads are difficult to quickly replace with alternatives such as bike lanes or pedestrian paths — institutional inertia and the reinforcing dynamics of prevailing social norms. Yet, they can also result from deliberate efforts by incumbents. For example, the fossil fuel industry draws on the tactics used by the tobacco industry to undermine efforts towards a just low-carbon economy (Malone, 2022). These tactics include intentionally promoting lock-in, political resistance, discourse that promotes delay and uncertainty, and political resistance (Lamb et al., 2020). In recent years these have been extended to include the funding of fake or disingenuous grassroots organisations that openly oppose actions that threaten incumbents (aka 'astroturfing').

Lock-ins describe mutually reinforcing path dependencies in technologies, institutions, infrastructures, and mindsets (habits, social norms, customs and beliefs) (Seto et al., 2016). For example, institutional investments in incumbent technologies and infrastructure, or education and human resources (e.g. professional training and standards), create long-term commitments that constrain the adoption of alternative trajectories in the future (William and Bonvillian, 2015). Carbon-intensive technologies and practices are particularly prone to entrenchment due to their large capital costs, feedbacks between socioeconomic and technical systems, and the longevity of associated infrastructure.

Political resistance to rapid transitions can come from incumbent industries and their workforces, who fear the prospect of closure and unemployment, and from ideological libertarians who distrust the impositions and perceived costs associated with climate policy. While the goal of accelerating decarbonisation may tempt governments to keep markets open to cheap imported products (often Chinese), this can strengthen resistance from domestic manufacturers and workers unions (Meckling and Nahm, 2018). Incumbent industries can create and exacerbate this resistance by intentionally producing and promoting narrative "**discourses of delay**", centred on claims of excessive economic cost, doubts about the integrity of science and scientists, loss of personal freedom/government interference, and the value of waiting to act (Coan et al., 2021; Lamb et al., 2020; Guenther, 2024). Finally, lobbying efforts by incumbent industries, and fears of backlash, can also create pressure for governments to keep policies such as fossil fuel subsidies intact.

To counteract this resistance, all actors (and governments in particular) have a crucial role to play in communicating the long-term benefits of rapid transitions, including their relatively low cost compared to the much higher cost of inaction and putting people at the heart of change using public participation (Devine-Wright et al., 2022). Regulation of misinformation would help to counteract some of the strategic efforts by incumbents to create political resistance. An integrated trade, industrial and regional development strategy that supports affected communities, re-trains for new skills, and re-purposes manufacturing towards healthier, better paid jobs in the new economy (e.g., offshore wind in the UK and Denmark) could ultimately lead to a deeper, faster and fairer transition by neutralising political resistance (Geels and Ayoub, 2023).

Cross-cutting influences on enabling and balancing feedbacks

Some factors can mediate or have cross-cutting influence on the dynamics described above and in Figure 3.2.1, with the potential for both positive and negative influence. Here, we highlight four: private finance, artificial intelligence, the media environment, and climate litigation.

Private Finance: The financial sector has an important role in facilitating the economic activities involved in positive tipping, and is being pressured to respond accordingly. For example, the Science-Based Targets Initiatives' recent net-zero standard for financial institutions rules out support for companies developing new coal, oil and gas projects (SBTi, 2025). Patterns of capital allocation that enable sustained financial flows into emerging low-carbon technologies and sectors can help overcome lock-ins, reduce perceived risk and build market confidence, particularly in underinvested regions and markets. Early, well-aligned investment creates positive feedback loops that reinforce other enabling conditions and accelerate transitions (Ameli et al., 2025). This requires significant changes in the normative guidelines, rules, and governance in the financial sector, including recognising the values of nature and conditioning financial profit on doing no harm (IPBES 2024).

Additionally, global warming and worsening weather extremes are accelerating risks to capital—including to fixed assets and human capital—leading certain regions to become uninsurable (e.g. home insurance in Florida) (Trust et al. 2025; Lamperti et al., 2019). Without insurance, mortgages and loans and other credit markets can no longer function, creating the potential for climate-driven systemic market failure and losses beyond the capacity of states to financially absorb or adapt. By realistically pricing systemic risks, private finance has the potential to trigger PTPs by unleashing considerable financial flows towards decarbonisation and nature conservation (Ameli et al., 2025) and away from activities precipitating ESTPs across many systems. Growing risks and financial losses could motivate decision makers to find solutions, however they could also have the opposite effect by accelerating the breakdown of global economic and political institutions.

Artificial Intelligence: Depending on who controls its use and to what ends, artificial intelligence could accelerate PTPs across systems in the following ways:

1. *Managing complex systems:* Modeling and optimisation can help manage the complex systems that are critical to climate adaptation and mitigation, such as the food system (Ayed and Hanana, 2021), renewable energy/smart grids (Ukoba et al., 2024), or transportation (Hosseini et al., 2025). AI can increase the efficiency of these systems (e.g. by using intelligent load management in smart grids, see Wang et al., 2024), and increase reinforcing feedbacks.
2. *Supporting technological innovation:* Machine learning tools can enable faster discovery and development of new technologies. For instance, by optimising the design of wind turbines (Ribeiro et al., 2025), or reducing supply chain issues with critical minerals.
3. *Promoting behavioural change:* Generative AI chatbots can be effective in challenging conspiratorial views (Costello et al., 2024), reducing the influence of climate change denial and delay on adoption of pro-climate behaviours. Large language models can also be effective in persuading people to change behaviour (Spaiser and Nisbett, 2025), though this introduces obvious ethical implications and risks (Chaudhary and Penn, 2024). Bespoke AI assistant tools could help democratise access to up-to-date climate science (see Biswas et al. 2025), increase climate awareness (Vaghefi et al., 2023), or assist in social deliberation processes such as citizen climate assemblies, including the Global Citizens' Assembly. Deployed at scale and customised to mobilise climate action, such AI tools could strengthen positive feedbacks.
4. *Monitoring social, technological, economic, and political dynamics* using large-scale data analysis, AI could provide early recognition of when social systems might be susceptible to PTPs or harmful tipping. For example, machine learning can be used with ecological monitoring and citizen science to automate biodiversity tracking (Plas et al., 2025), while analysis of vehicle advertisements can be used to detect tipping towards large-scale electric vehicle adoption (Boulton et al., 2025). Better monitoring and understanding of target systems might help to identify opportunities and optimal timing for interventions.
5. *Modeling and simulation tools:* AI can explore a wide range of options including the effectiveness of different policy interventions or activism scenarios. Generative AI-enhanced agent-based models could simulate different international climate negotiation strategies (Vezhenevets et al., 2023). AI-enhanced digital twins could be used to model urban sustainability transformations.
6. *Digital Public Infrastructure:* other digital technologies augmented by AI can enable a rapid transition towards climate and other Sustainable Development Goals with the deployment of digital public infrastructure (DPI). The current, fragmented approach to knowledge acquisition and financial, technological and capacity-building resources have held back structural transformation and exacerbated inequalities. Open, safe, and inclusive DPI could allow AI to promote a more shared prosperity at relatively low cost and without impinging on the sovereignty of nations, communities, or individuals (Zuckerman, 2020).

However, AI technologies also come with substantial risks for PTPs. Data centres are known for their substantial water and energy consumption, and have been linked to increases in planned fossil fuel capacity in certain markets. It will be vitally important to minimise these negative environmental impacts as the AI market grows, through a holistic set of measures such as energy and water efficiency, demand flexibility, alternative transmission technologies, and renewable energy sources (Numata et al., 2025). AI tools could also be used to spread climate misinformation (Noor 2025). And concerns have been raised with respect to data and technology ownership (Strowel 2023; though there are recent promising developments). Ultimately, these technologies are here to stay, we have therefore to find ways to utilise them to empower humans to tackle challenges such as preventing ESTPs while minimizing their burdens on the earth system.

The Media Environment: The mass media has a powerful role in shaping public discourse, perceptions and responses to the climate and nature crisis, including how the policy agenda is set at all levels of governance. As is the case with other cross-cutting influences, this power can be used to build public and political support to accelerate climate mitigation, or for the opposite ends: to undermine public trust in climate science and the need for rapid action (Falkenberg, 2022; Ruiu, 2020; Bolzen and Shapiro, 2017). A study of 59 countries finds that global media coverage of climate-related stories has grown significantly in recent years, from around 47,000 articles in 2016-17 to around 87,000 in 2020-21 (IPCC, 2022). In scrutinising the actions of governments, corporations, and other actors, the media can shine a light on corruption, scandal and injustice and hold drive the public to hold actors accountable for their policies and actions.

Other forms of media, such as films and books, also have the potential to 'tip' public opinion in a profound way—as, for example, Harriet Beecher Stowe's Uncle Tom's Cabin did in the case of the abolitionist movement, helping precipitate the American Civil War. Films such as Al Gore's An Inconvenient Truth, Leonardo Di Caprio's Before the Flood and Don't Look Up!, Sir David Attenborough's BBC documentary Climate Change—The Facts, Franny Armstrong's The Age Of Stupid (2009), and Saci Lloyd's The Carbon Diaries (2015); books such as Kim Stanley Robinson's Ministry of the Future (2020); opinion pieces in newspapers and magazine articles such as David Wallace-Well's The Uninhabitable Earth (2017) have raised awareness about the climate and nature crisis but have remained unconnected to the wider movement.

Occasionally, an artwork does coordinate advocacy on a broader scale and can be instrumental in creating momentum for meaningful change and a critical mass of committed actors. A recent example is the film Ocean, produced by Silverback Films and Open Planet Studios and narrated by Sir David Attenborough. This film's release was perfectly timed to put pressure on political leaders to ban bottom trawling in Marine Protected Areas (MPAs) and to conserve 30% of the world's oceans by 2030, as agreed in the Kunming-Montreal Global Biodiversity Framework.

Social Media is a powerful tool for spreading information about climate and nature issues. However, while social media algorithms can result in the quick spread of information and awareness and mobilise support for climate action, they can also spread misinformation and increase polarisation by creating information silos, increasing homophily, and promoting the spread of extreme content. Polarisation, to the extent that it reduces support for general public goods and is leveraged to delay a transition away from incumbent systems, is a barrier to decarbonisation. Additionally, as online social networks replace more local or place-based ones, civic capacity and the incentive to contribute to local public goods can become weaker (Zhang, 2025).

Climate Litigation: Strategic climate litigation can enable the conditions for PTPs by generating court decisions that require governments to accelerate efforts to address climate change, such as developing more stringent national climate plans (Averchenkova et al., 2024; Higham et al., 2022) and implementing mandates for private sector actors. They can also enable PTPs by creating climate-related risks for the private sector, thereby incentivising them to adopt more sustainable business practices. Climate litigation efforts also shape public discourse on climate change and the rights of future generations (Wewerinke-Singh & Ramsay, 2024) in ways that may support policies to enable PTPs.

As of 2024, 2967 climate cases had been brought in almost 60 countries. Over 226 new cases were launched in 2024 (Setzer & Higham, 2025). This expansion looks set to continue, as evidenced by the release in 2025 of advisory opinions on climate change by the International Court of Justice (ICJ) (Obligations of States in respect of Climate Change), the Inter-American Court of Human Rights (IACtHR) (Climate Emergency and Human Rights), and the International Tribunal on the Law of the Sea (ITLOS) (Climate Change and International Law). These legal opinions have laid the groundwork for greater scope for liability for both state and non-state actors. In its 2025 Advisory Opinion, the ICJ explicitly acknowledged that a State may be liable where, "it has failed to exercise due diligence by not taking the necessary regulatory and legislative measures to limit the quantity of emissions caused by private actors under its jurisdiction" (IJC, 2025, para. 428). By this finding, the ICJ opened the door for new claims against states for failure to regulate the fossil fuel industry with respect to production, consumption, granting licenses, and providing subsidies (para. 427).

A growing number of cases are being brought by individuals and civil society organisations (CSOs) against states (Leghari v. Federation of Pakistan, 2015; KlimaSeniorinnen, 2024) and local authorities (Finch on behalf of the Weald Action Group v. Surrey County Council, 2024). One of the leading cases of this kind, State of the Netherlands v. Urgenda Foundation, led to the phase-out of coal power stations in the Netherlands and stricter climate policies (Urgenda, 2019). Cases are also being brought against businesses. In Luciano Lliuya, a Peruvian farmer sought compensation for loss and damage from a German energy company in German courts (Luciano Lliuya v. RWE). The court dismissed the specific case; however, it held that businesses are potentially liable to pay compensation for historical emissions that contribute to climate change today. Other forms of climate litigation include anti-greenwashing cases (FossielVrij NL v. KLM, 2024) and shareholder rights litigation (Client Earth v. Shell plc et al., 2024).

At the same time, some industry actors and governments have used litigation to slow down or halt action on climate change (Setzer & Higham, 2025). Arguably, this adverse reaction is a manifestation of 'balancing forces' that seek to maintain the status quo, dampening progress towards PTPs. To enable PTPs, such balancing forces must be countered with renewed climate litigation efforts, creative advocacy, and greater financial support for individuals and CSOs engaged in climate litigation. It is recommended that advocacy organisations strive for greater coordination of strategic litigation efforts for enabling PTPs; at the same time, it should be recognised that diverse and autonomous approaches will be taken in different regions and countries. As climate litigation efforts evolve, the use of ESTPs science should be tracked, and this data used in developing strategies for future cases that can help to enable PTPs.

Box 3.2.2: PTP theory operationalised at the local scale: creating the conditions for a shift to sustainable eating habits in Brøndby, Denmark.

A new project in the Danish suburban municipality of Brøndby exemplifies the operationalisation of positive tipping point theory to promote rapid, sustainable dietary change at the local/municipal level. Initiated in 2025, this project relies on community engagement, leadership development, and gastronomic innovation to promote the adoption of plant-rich diets among Brøndby's 40,000 culturally diverse residents.

In Brøndby, tipping point theory is translated into action by first identifying and empowering informal local leaders who can effectively influence their social networks to adopt sustainable eating habits. Community leaders receive specialised training in sustainable cooking and community mobilisation, thus enabling them to normalise plant-rich diets within their social circles. These interventions aim to initiate a 'complex contagion' process, where behaviours spread within communities due to normalisation and social reinforcement.

By combining food joy and appealing plant-rich meals in routine community settings including schools, workplaces, canteens, and community events, the project ensures sustainable dietary choices are visible, accessible, and socially desirable. Such visibility is amplified through strategic communication efforts and public events, including the high-profile "Brøndby Challenge", reinforcing community commitment and broadening the movement.

The Brøndby Project has been developed jointly by the Danish not-for-profit foundation Democracy x, culinary entrepreneur and co-founder of the New Nordic Kitchen movement Claus Meyer, the Global Systems Institute at the University of Exeter, and the municipality of Brøndby. It is designed to offer a replicable/adaptable framework for municipalities globally, demonstrating (if successful) how carefully designed community interventions can effectively promote positive tipping points towards sustainability.

3.2.3 Policy sequencing, packaging and stringency

Different policy instruments or actions have distinct outcomes, and are often tailored to the specific national context and sector (Grubb et al., 2024) (see Figures 3.2.3. and 3.2.4). Creating the enabling conditions for PTPs and achieving rapid decarbonisation goals requires multiple policies and actions to bring about rapid systemic change. However, the overall effectiveness of different combinations of policies depends on how different interventions interact, and how they are sequenced (Stechemesser et al., 2024; D'Arcangelo et al., 2023). Once policymakers understand where in the transition phase a system is (see 3.1), they can begin to identify the most effective (1) combinations of policies ("policy packages" or "policy mixes"), (2) sequences of interventions ("policy sequencing"), and (3) intensity of such efforts ("policy stringency") to accelerate progress—or create lock-in and resilience once desired change has been achieved.

Policy packages refer to the combination and interaction of multiple instruments over time. Complementary and reinforcing policy packages or mixes can increase the potential impact of decarbonisation efforts. For example, multiple measures may be necessary to solve different market failures or enhance both the supply and demand of a new technology. Redundant or conflicting policies can increase mitigation costs or administrative complexity. For example, public investment and regulatory instruments can both enhance and detract from each other. Public investment in alternative infrastructure and technology can increase the acceptability of standards or bans. At the same time, investment in R&D or infrastructure development can fail due to permitting regulations that hinder expansion of new technologies (e.g. limitations on cross-jurisdiction permitting in the U.S. have slowed the build out of regional transmission lines necessary to support wind and solar).

Policies will interact differently in different contexts and sectors, and the research on policy mixes is still nascent (OECD, 2025; Meadowcroft and Rosenbloom, 2023). However, the specific mix of policy instruments should be tuned to the transition phase (see below) and to political and public readiness or appetite for change. Strategic policy mixes can increase sociopolitical acceptance for climate policy and decarbonisation by including provisions that compensate potential losers (e.g. workforce retraining or cash transfers in coal communities), increasing the salience and presence of co-benefits (e.g. local health benefits), and integrating climate and social policy (Bergquist et al., 2020).

Some policies or interventions will only be effective when introduced sequentially. How **policies are sequenced** can therefore enhance or detract from policy effectiveness (Meadowcroft and Rosenbloom, 2023). Policies that create the enabling conditions for a subsequent intervention to be effective should be introduced first. In particular, policies that deliver credible and tangible benefits that are traceable to a policy quickly can garner greater support among the public, as was the case for Social Security in the US (Jacobs and Mettler, 2018). How the extent of benefits or costs are sequenced can have large repercussions for the resilience of a policy. Additionally, green industrial policy that creates strong economic interests in the green transition can be self-reinforcing if those interest groups start to lobby for continued or more stringent transition policies (Meckling, 2021).

Increasing **policy stringency** in the short term, self-propelling feedbacks can be unleashed earlier, thereby reducing the need for policy intervention and public investment in the longer term and enabling tax revenues to be better spent on other priorities. Tax and subsidy combinations can be designed to bring forward the crossing of the cost parity threshold between clean technologies and fossil fuels, while being revenue neutral for the government. For example, a tax of $160 on the sale of each mid-range internal combustion engine car in Europe in 2023 could fund a subsidy of $1,600 on the purchase of each mid-range electric vehicle, achieving ownership cost-parity while maintaining revenue neutrality (Lam et al., 2023).

In the financial sector, increasing the capital requirements for banks holding fossil fuel assets is another powerful tool to raise the cost of capital for high-carbon activities and accelerate the phase-out of fossil fuel finance (Ameli et al., 2024). At the same time, stringent policies can be more difficult to pass and can create backlash, even when they are carefully designed to offset costs, as was the case with the Canadian carbon tax and dividend policy (Mildenberger et al., 2022). Starting with policies that are targeted, specific, and create upfront tangible benefits (e.g. subsidies) can create appetite for more stringent climate policy in the future (Fesenfeld et al 2022; Sewerin et al., 2023).

Tuning the policy or intervention to the phase of the transition

Considering the phase of the s-curve a transition is in can help to identify which measures might be most relevant. In Figure 3.2.4. and in the text below, we describe which public policy measures may be most effective at different points along the tipping trajectory.

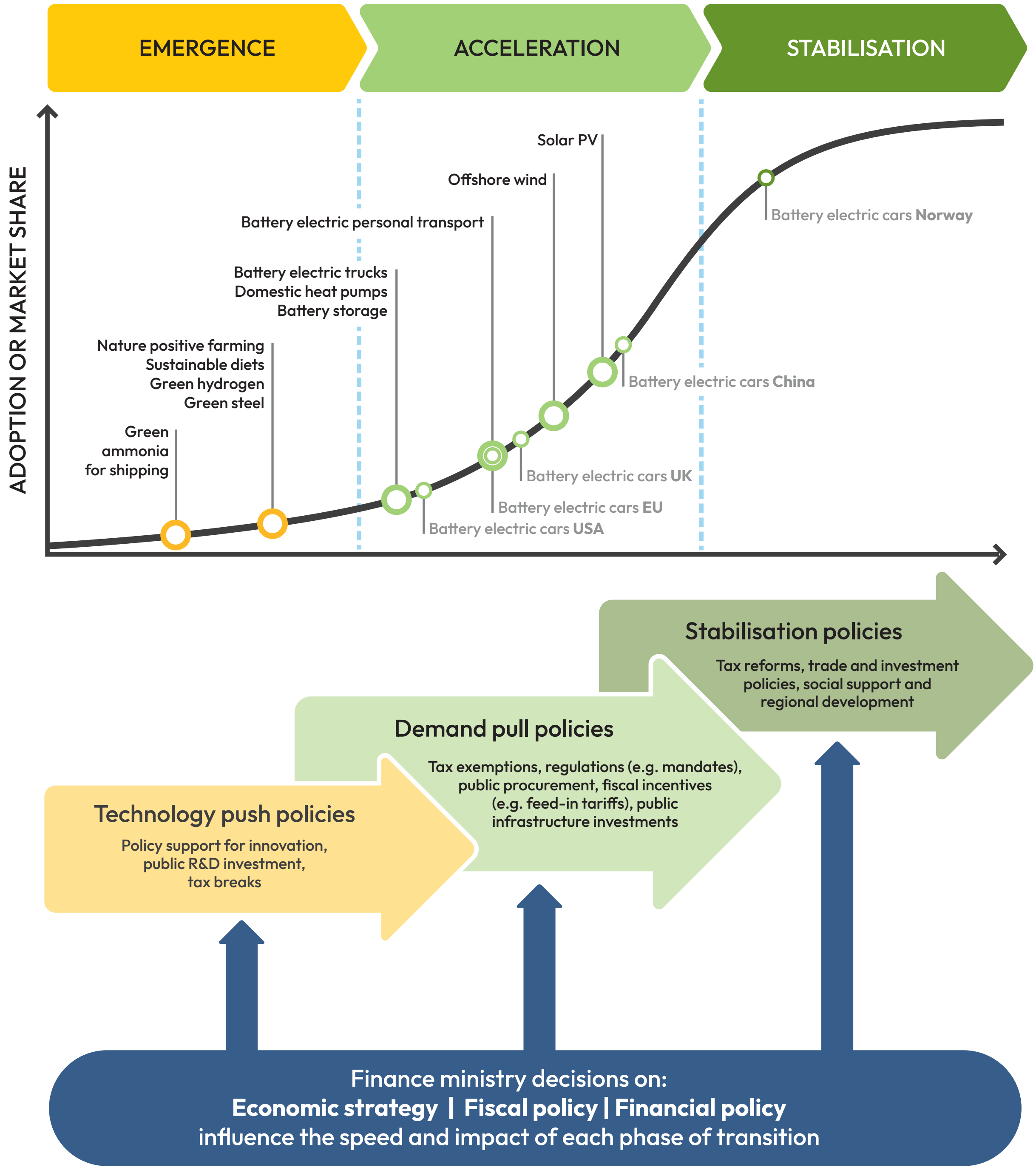

Figure 3.2.4. Sequencing policy interventions along a transition curve to enable PTPs. Based on Figure 2 of Sharpe et al., 2025, modified to show sector update assessments from Chapter 3.3. for global adoption of key transition technologies (orange circles, black text), and market share of battery electric cars in 5 key markets (USA, EU, UK, China and Norway) to illustrate potential different states of adoption in different markets or jurisdictions'

Phase 1: Emergence.

The early stages of a transition are characterised by the emergence of an innovation, or set of innovations, with the potential to address an identified problem or need. At this stage, innovations are vulnerable to inconsistent messaging, uncertain policy and market environments, and barriers to commercialisation (e.g. high fixed costs before economies of scale can be realised).

Important interventions at this stage include: building awareness and support among key stakeholders through public engagement and media campaigns and setting clear and credible policy goals. Additionally, early public investment in R&D and skills development (e.g. workforce development) as well as tax breaks can help de-risk and incentivise private investment to support early stage innovation. Roadmaps and targets can help direct investment and coordinate R&D activities. Creation of niche markets, which provide a space for early commercial products to improve, can be facilitated through public procurement or green industrial policy (Meckling 2021).

Niche markets can also depend on early adopters to increase the visibility and create the social proof necessary for those who are less certain or committed to adopt the technology or practice. In this early stage, one challenge can be achieving sufficient early adoption to destabilise status quo practices, behaviours and norms, which can themselves be self-reinforcing through the same social dynamics that eventually lead to destabilisation (Constantino et al., 2022; Young et al., 2024). Strategic policy introduced by businesses and governments can incentivise early adoption through targeted education or subsidies and taxation, among others (Nyborg et al., 2016). For example, businesses might promote the use of bikes or public transport, encourage different dress codes and energy and water conservation, among other actions.

Phase 2: Acceleration.

The middle stage of a transition is characterised by accelerating diffusion of behaviour, technology or new norms to a wider population—and weakening strength of incumbent technologies and industries.

In this phase, policies such as continued and broad use of subsidies and taxes, purchase incentives (i.e. to increase affordability), and development of supportive infrastructure can be critical to support broad adoption. Regulations and mandates that force the private sector to reallocate investment from the old to the new technology can drive innovation, economies of scale, and learning, improving the attractiveness and affordability of new technologies.

However, passing mandates can prove politically challenging unless there is already public acceptance for the new or alternative technologies or strong enough private sector interest or an organised civil society response. Designing policies, such as public education efforts, that create new constituencies that support the alternative behaviour or technology, or that create lock-in to the alternative while simultaneously breaking out of lock-in to the incumbent way of doing things, can create positive feedbacks that are important for transitioning from phase 2 to phase 3 (Trachtman et al., 2025).

Phase 3: Stabilisation.

In the late stages of a transition, the new regime can become stabilised or resilient due to system characteristics or strategic actions to “lock in” or entrench desirable change through the same reinforcing feedbacks described in the previous section. For example, economies of scale or network effects, where benefits to use of a technology increase in the number of adopters of that technology (e.g., electric vehicles become more desirable as more people adopt them and more charging stations are built), create reinforcing feedbacks that can make it costly or difficult to revert to prior or alternative technologies.

Stabilisation can also happen through long-term infrastructure investments (e.g. the build out of renewable energy and decommissioning of coal plants, expansion of trains and bike paths etc.) which reduce the accessibility of alternatives, the emergence and institutionalisation of new social norms (Young 2024), the creation of strong coalitions and constituencies that benefit from the new regime in phases 1 and 2 and so have incentives to ensure its continuation (e.g. new workforce, firms and trade associations, consumers), and supportive and potentially increasingly stringent policy measures (e.g. building codes, emissions standards, carbon prices). These measures need to be coupled with continued efforts to promote the phase-out of fossil fuels and weaken the role of incumbents in resisting changes (e.g. to infrastructure) and in shaping policy and public narratives, including through misinformation.

Dampening effects are present at each of these phases as existing actors respond to protect their self interest. Precautions to avoid or reduce unintended consequences and measures to deliver widespread benefits that are salient and linked to the transition to a new behaviour or technology and that ensure that those who stand to lose from the transition are engaged in the process through participatory decision-making and compensated for their losses can help to reduce backlash and increase continued support for the transition.

3.2.4 The domino effect of positive tipping cascades

Policies and other actions that promote sustainable transitions in one sector can sometimes accelerate transitions in other sectors, creating a domino effect or cascade (Sharpe and Lenton, 2021; Eker et al., 2024). The improvements in battery technology in the last few decades, for instance, cascading from consumer electronics to buses, cars and then into stationary electricity storage in the power sector and long-haul transport, is a good example of positive tipping across multiple sectors and countries (Walter et al. 2023).

These cross-sectoral interactions reinforce the feedback loop of demand increase, cost reduction and quality improvement, and have led to rapid adoption of batteries to replace fossil-fuel based energy supply.

A model of four sectors—renewable power, residential heating, light road transport (cars) and heavy road transport (trucks)—show a that coordinated policy mixes (and mandates in particular, see Figure 3.2.5) can significantly bring forward tipping points in these sectors (by 2-8 years) and increase the potential for tipping cascades (Nijsse et al., 2024).

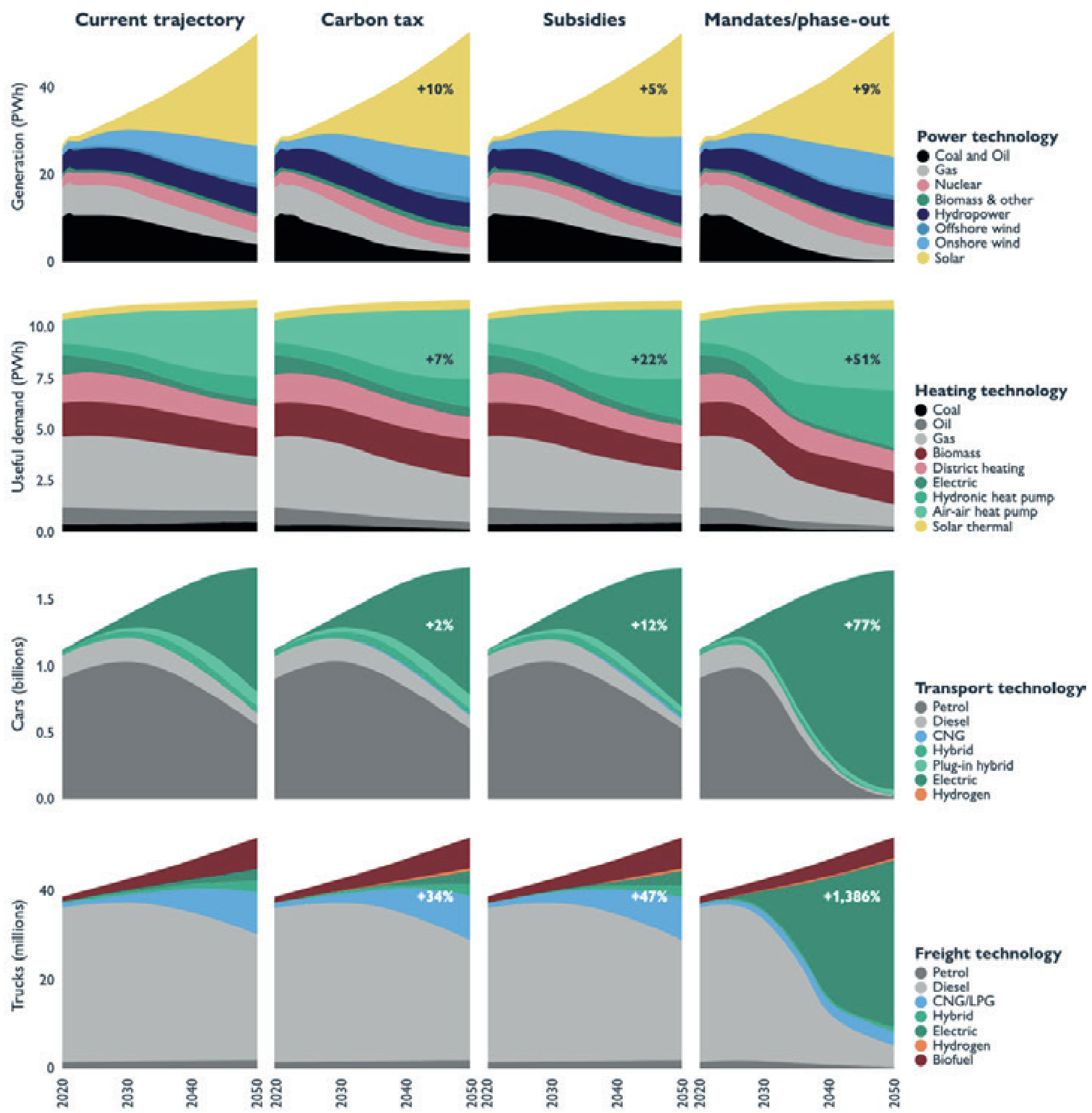

Figure 3.2.5: Effect of different policy instruments on the global technology mix in four sectors. Percentage growth is shown for selected green technologies: in the power sector it is the sum of wind and solar; in the heating sector it is all types of heat pumps; in the transport sector it is all types of full electric vehicles (Nijsse et al., 2024. Reproduced with permission).

Other policies can further enhance the effectiveness of technology deployment policies, for example: policies to reduce energy demand to help power system balancing; policies to improve home insulation to lower heating and cooling demand; policies to increase heat pump efficiency; and building standards requiring that houses act as thermal batteries (OECD, 2025). Such demand-side measures can amplify the effectiveness of supply-side policy mixes and trigger positive tipping cascades. Furthermore, the common drivers of social and behavioural changes for demand-side mitigation, such as environmental identity, social norms, and self-efficacy, can create spillovers across different consumption domains (Maki 2019; Behn 2025). Behavioural changes in one end-use sector, such as residential energy, can cascade into other sectors such as food and mobility. In addition to their cross-sector cascades for decarbonisation, demand-side measures can also improve energy security, enhance quality of life, and reduce the costs and risks associated with carbon removal technologies (Creutzig et al., 2022).

3.2.5 Social and political considerations when enabling PTPs

Creating the enabling conditions for PTPs involves some degree of anticipation and influence over the evolution of a system—as well as some level of agreement about the alternative desirable system state. This report defines PTPs as those that contribute to rapid decarbonisation. However, what is "positive" is a normative question, and even with the goal of decarbonisation, there are many possible pathways—and these will be supported and contested by different actors (Pereira et al 2024).

Identifying shared goals and where to intervene can thus be challenging when considering complex social-ecological systems with emergent dynamics, diverse viewpoints and priorities, and inevitable tradeoffs. Strategic foresight and scenario building can help practitioners to understand system dependencies and anticipate different potential system responses (Ramirez and Wilkinson, 2016). For example, strategic foresight tools can help governments to better understand, project and anticipate market developments, technological trends, or how changes in public opinion or behaviour might evolve, as well as how interlinkages between systems might change. This is important as deliberate attempts to create rapid change are likely to be met with backlash without additional considerations about distributional consequences, impacts on social identities and communities, and psychological aversion to rapid change.

Ensuring a just transformation can increase the sociopolitical viability of PTPs, while also achieving important normative goals. Just sustainability transformations have distributional, procedural and recognitional dimensions. It is critical that the distributional consequences of a transition are considered, and that measures are developed to ensure that those who face losses are adequately compensated and that social outcomes, including equity, are prioritised alongside decarbonisation goals (Bennett et al 2019, Avelino et al 2024, EEA 12/2024). In addition to identifying different potential transformation scenarios, practitioners can use scenario building methods to consider the potential distributional consequences of different interventions, and preferences about inevitable tradeoffs that emerge.

Decision-making processes that enable broad participation are key to achieving procedural justice, and are likely to increase sociopolitical acceptance. Asking the question "transforming towards what?" requires broad inclusion of diverse voices and not just experts to guide what aspirational futures could be enabled (Juri et al 2025). Community engagement is increasingly viewed as critical to create social & democratic legitimacy for strategic efforts to alter the status quo. Measures to bring individuals and communities on board in early stages—and to give them a say in the decision-making—can increase the social acceptance of necessary changes and, depending on who is represented in these efforts, ensure greater benefits and equity. Participatory scenario development is one tool to build anticipatory governance and futures literacy as well as generate useful outputs in terms of the futures that people both aspire towards as well as those they want to avoid (Pereira et al 2021).

Deliberative democratic methods can also be used to take regular 'temperature checks' of ongoing efforts at systems change—allowing flexible and adaptive responses as well as identification of unintended consequences. For example, the Global Citizen Assembly takes a two-pronged approach to community engagement in decision-making by creating a Global Mini-Public and Community Assemblies. The Global Mini-Public is a transnational deliberative mechanism to legitimise global-scale decisions, facilitate long-term thinking and demand justice across scales and borders. In contrast, Community Assemblies are local deliberative spaces to support the local deliberation of Earth System risks that foster local stewardship in the management of these risks. Together, the two levels could create a two-way knowledge bridge: community assemblies can feed insights and lived experiences into the global mini public, anchoring global decisions in local realities, while the global mini public can return globally deliberated visions and mandates to local communities, creating a reflexive learning loop across scales (Curato et al. 2025). These tools for community engagement could advance polycentric Earth System governance by supporting a multi-level governance architecture, aligning local agency and global coordination in response to interconnected tipping point risks. Ultimately such approaches can foster cross-scale and trans-local networks of learning, knowledge co-production, cooperation and capacity building. It is important that politicians commit to implementing the recommendations of these assemblies.

3.2.6 Building Coalitions to Facilitate PTPs

Efforts to create PTPs are often met with resistance to change, as well as specific counter-measures from powerful, well-financed incumbents trying to maintain the status quo. The power asymmetry in the incumbents' favour can be difficult to overcome. Coalitions, which are broadly defined as "alignments of disparate groups across government, business and civil society, united by common interests" (Roberts et al., 2018; Rayner & Bonnici 2021) are vital in the creation (or undermining) of PTPs for rapid decarbonisation. Actors who are limited in what they can achieve individually can strengthen their combined agency by forming broad, deep, and interconnected ecosystems of influence (Laybourn-Langton et al., 2021; Weible, 2018; Schmidt, 2015). Coalitions allow actors across scales and sectors to pool their resources, learn from each other, and build collective and strategic capacity to bring about PTPs in the face of strong incumbent interests and substantial uncertainty (Matti et al 2025; Ganz 2009).

Coalitions can be detrimental when they are not well organised. Common pitfalls include dilution of goal strategy, lack of clear decision structure or ownership, and difficulty achieving consensus (Tulder et al., 2018). Coalitions with coherent and unified goals tend to have the most decisive influence on policy (Weible and Sabatier, 2018). When coalitions have a shared interest in the new technology they can reinforce the new technology or behaviour through policy feedbacks (Meckling et al., 2015; Rosenbloom et al., 2019). Furthermore, clear roles and learning feedback loops that allow the coalition members to adapt and learn as they pursue their shared goal (Zack et al 2023).

Steps to consider in building coalitions for PTPs:

- **Map and model:** define the system, its boundaries and its current state and create a map of the field including actors.
- **Identify and define:** identify actors with aligned values and interests around a decarbonised future state and complementary resources. Identify formal and informal leadership among key actors. Define clear goals and a shared approach and theory of change to guide the work
- **Convene:** bring together coalition partners to build trust and design shared working and decision-making structures with clear roles and commitments from coalition partners (Zack et al 2023).
- **Work with friction:** accept that systems change takes energy and includes systems learning where conflicting interests compete over scarce resources, make sure to develop mechanisms for transparency, accountability and conflict resolution (Zack et al 2023, Rayner & Bonnici 2021).
- **Invest in capacity building and learning:** develop the necessary environment (Heifetz 1998) to enable adaptive learning and new roles required by the uncertain nature of systems transformation. (Rayner & Bonnici 2021, Zack et al 2023)
- **Include citizens and outside actors:** Involve citizens and other stakeholders early on to identify shared visions and to counter inertia and zero-sum-logics, contribute to shared will formation, and broader norms change.

As described in the first Global Tipping Points Report (2023), recent work suggests that broad consensus-building may not be the most effective way to catalyse rapid climate action. Pioneering, high-ambition small-group coalitions committed to ambitious climate and nature goals may be able to initiate self-propelling virtuous cycles of cooperation involving specific sectors and corporate partners. These 'climate clubs' could lead others to follow (Sharpe, 2023).

Box 3.2.3 below describes an emerging coalition for positive tipping points in climate and health.

Box 3.2.3: A Climate and Health Coalition for PTPs

Opportunities exist for the health sector to bring together a powerful, well organised coalition of actors committed to a joint programme of rapid climate action and improved health.

The health sector, which employs more than forty-six million people, is responsible for approximately 5% of greenhouse gas emissions and 10% of Global World Product. Health professionals tend to be trusted messengers, well-placed to articulate the health and wellbeing benefits of a rapid transition to a sustainable future. However, until recently they were largely unaware of the systemic risks to health and healthcare provision posed by intensifying heatwaves, wildfires, floods, hurricanes, tornadoes and other climate-related hazards.

In Glasgow, November 2021, local and national-level initiatives coalesced into an international movement via the WHO CoP26 Health Programme. At CoP26, The UK National Health Service (NHS) was an early mover in announcing a comprehensive, evidence-based net-zero strategy for the health sector, demonstrating that ambitious decarbonisation was possible. By the end of CoP26, fifty-two countries had signed up to this WHO-led movement, which has now grown into a coalition of over eighty countries. These country level commitments can enable normative shifts at all levels of health bureaucracy and wider society, shifting working practices, financing, and power dynamics in transformative ways. Global networks such as the Global Climate and Health Alliance and the WHO–WMO Climate and Health Joint Programme, are now engaging with countries to accelerate towards climate-resilient, sustainable, low-carbon health systems.

3.3 Progress on Positive Tipping Points in Key Systems

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Key messages

- **Renewable energy is scaling rapidly but unevenly. Solar PV is doubling capacity every 2–3 years and growth of wind power is also strong. Reducing planning delays, providing grid infrastructure, and finance can accelerate change.**
- **Battery prices have plummeted by 84% in the last decade and capacity is growing exponentially, underpinning mobility and power sector transitions.**
- **Electric vehicle adoption is accelerating in leading markets. China has become the dominant manufacturer. Norway has near total adoption. Price parity, battery performance, and charging availability are key determinants of mass adoption.**
- **Policy mandates and coordinated finance and investment are essential for bringing forward positive tipping points in the energy system.**
- **Heat pumps are a critical lever for decarbonising buildings, but face high upfront costs and other barriers including a shortage of skilled installers. Improved policy incentives, financing (e.g. cheap loans) and consumer trust are vital.**
- **Affordable green hydrogen could unlock hard-to-abate sectors such as those requiring industrial heat (eg steel and cement). Current costs are 2–3 times higher than grey hydrogen but learning curves could lead to price parity.**
- **Clear policy supported by financial incentives can enable farmers to switch to more sustainable production methods and build resilience to extreme weather events.**
- **Widespread support for rapid decarbonisation can be strengthened when benefits are evenly distributed, e.g. through lower bills, better health outcomes and improved quality of life.**
- **Supportive policy and public procurement can help to normalise and spread sustainable behaviours, e.g. through promoting active transport, sustainable eating.**

Introduction

This chapter provides short updates on progress towards positive tipping points in 11 key sectors or systems essential to mitigating the threat of Earth system tipping points, which have been highlighted in previous reports (Meldrum et al., 2023; GTPR 2023).

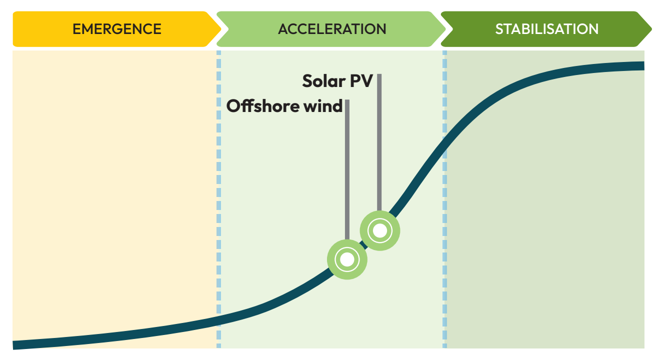
ENERGY & POWER: SUPPLY

Renewables, especially solar PV and wind power, offer the only affordable solution to rapidly decarbonise energy grids and provide plentiful, low-cost power. Growth in renewable energy generation firstly reduces demand for new fossil fuel based generation as global electricity demand grows, and will replace existing coil and gas generation capacity as older infrastructure is decommissioned.

Deployment of solar and wind power are essential for enabling emission reductions in end-use sectors like transport, heating and industry (see below). The potential to do so is growing every day through innovation in, for example, electric vehicles, heat pumps and industrial processes.

SOLAR PV AND WIND GENERATION

Replacing all electricity generation with renewable sources could **remove 26% of current global greenhouse gas emissions from fossil generation, and more through enabling electrification in other sectors.**



Progress:

Combined, solar PV (1865 GW) and wind (1133 GW) provided 15% of global electricity generation capacity in 2024. **Solar PV is the fastest growing source of energy generation in history** (Ember, 2025a) and dominates growth in electricity generation capacity, increasing by over 30% (452GW) globally in 2024, meeting 40% of the global increase in electricity demand (IRENA, 2025). 99 countries have doubled (or more) the amount of electricity they produce from solar power in the last five years, from emerging economies to those with the largest power systems, and 20 countries now generate more than 15% of their electricity from solar power (Figure 3.3.1a). Wind deployment (7.9% capacity growth in 2024) is also projected to continue with steady or slightly accelerated growth, with 19 countries generating more than 15% of their electricity from wind in 2024 (Figure 3.3.1b).

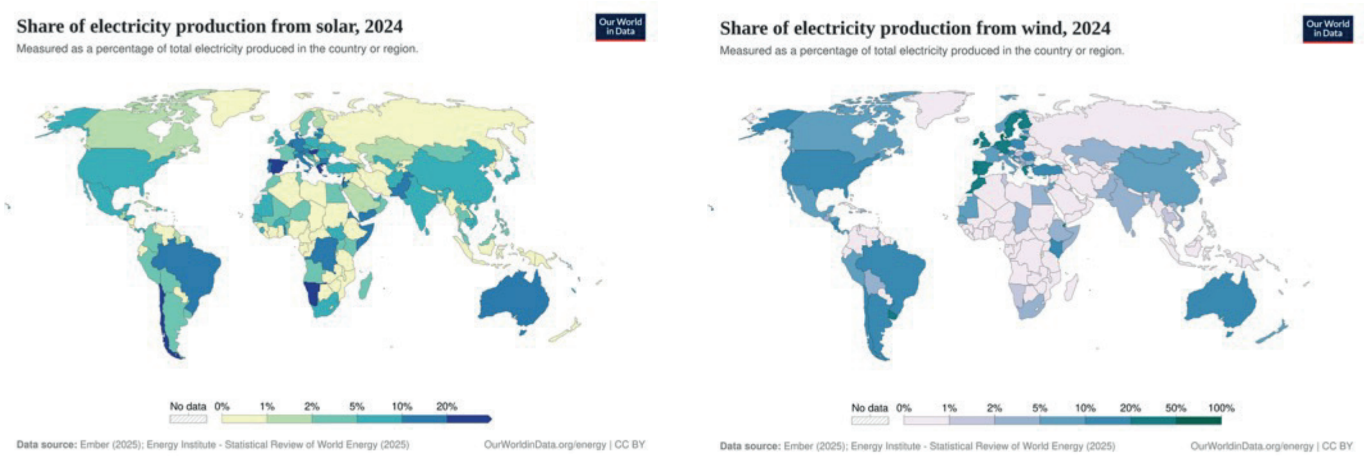


Figure 3.3.1: The share of electricity production from (a) solar and (b) wind power in world countries in 2024 (Ember (2025); Energy Institute - Statistical Review of World Energy (2025) – with major processing by Our World in Data).

- **China:** tripled solar PV capacity additions in 2 years from 2022 to 2024, installing 277 GW last year. China also realised a new record in wind capacity additions of 79 GW (IRENA, 2025). New fossil capacity additions fell in 2024 compared with previous years, despite growth in electricity demand (Ember, 2025a). China dominates global production and innovation in renewable technologies; with more than enough supply for its domestic market, it is now actively investing in building new offtake markets in South-East Asia, Africa and Latin America (RMI, 2024).
- **USA:** installed a record of 50GW new solar PV capacity in 2024, with a moderate increase in wind capacity (5.1 GW). Combined, wind and solar overtook coal power for the first time in 2024, generating 17% of the USAs electricity (Ember, 2025a). This growth trend is expected to continue, with solar and battery storage expected to contribute over 80% of new capacity additions in 2025 (U.S. EIA, 2025). **EU:** installed 66GW of new solar PV capacity in 2024 (4% increase from 2023), and 16 GW of new wind capacity (Wind Europe, 2025). Fossil generation fell in the EU while both power demand and electricity exports grew as clean energy growth significantly outpaced demand growth (Ember, 2025b).
- **India:** energy demand is set to more than double by 2050. While early in its transition, dependence on fossil fuel imports provides a strong incentive for renewables deployment, and capital is rapidly shifting into renewables deployment and manufacture. India doubled solar capacity additions in one year from 2023 to 2024, adding 23 GW (RMI, 2025a).
- **Emerging markets and global South:** low costs of renewables are enabling very rapid deployment in many countries in the global South, which stand to gain by reducing fossil fuel imports while increasing electricity access. Capital expenditure on generation is swinging rapidly to renewables (87% of capex in 2024), and deployment is accelerating rapidly, even outpacing that in the global North in terms of generation share vs. fossil fuels. New markets can emerge and grow very fast. Pakistan emerged rapidly as one of the world's largest markets for solar panels in 2024, importing 17 GW of panels (Ember, 2025a). Low cost exports of solar panels from China, which is actively building new markets in the global South, are a key driver of growth (RMI, 2024).

BALANCING OR RESISTING CHANGE

- **Policy barriers** remain in many markets, including complex permitting and auction processes for renewables, a lack of support for enabling flexible storage and demand-side flexibility.
- **Grid infrastructure investment** often lags growth in renewable deployment, creating bottlenecks. Battery storage and demand flexibility may mitigate this need for grid expansion .
- **Negative electricity prices** harm the business case for renewables. Per kWh, solar sometimes only get 60% of the income compared to an average asset (Ason and Dal Poz, 2024, Hillion, 2025).
- **Continued investment in, and subsidies for fossil fuels** slow down the growth of renewables.
- **Growth in total electricity demand still outpaces clean energy deployment**. Demand from electrification of sectors like transport and heating, as well as demand from data centres and crypto mining contribute to this demand growth (RMI 2025b). Hotter than average temperatures in 2024 were a significant cause of increased electricity demand, and drove increased fossil generation resisting phase out (Ember 2025a).

REINFORCING OR ENABLING CHANGE

- **Renewable energy costs continue to fall while products improve in quality** (e.g. more efficient solar cells, larger wind turbines) driven by economies of scale and learning by doing, especially due to very high production volumes in China.
- **Battery storage is getting much cheaper** and markets are being designed to make them profitable. This **technological reinforcement** improves the business case for solar developments, making them more competitive against fossil fuels and even cheaper than gas generation in some markets (e.g. Germany)(Ember, 2025b). The world's first 24-hour solar PV project is due to come online in Abu Dhabi in 2027, enabled by low-cost battery storage. **Digitally enabled smart-metres and consumer interfaces** enable consumers to save money by shifting demand to periods of abundant supply.
- **Energy insecurity** and volatile/rising pricing of fossil fuels have increased the rate of solar deployment in some countries. Of the 15 countries with the highest solar shares in 2024, 7 were in the EU, where energy independence from Russia is an important driver.
- Although gross solar production and installation statistics are dominated by **China**, solar is experiencing rapid growth worldwide, with 99 countries doubling their installed capacity in the last 5 years. 21 countries generate more than 15% of their electricity from solar power, up from 3 in 2020. As well as China among BRICS nations **Brazil** and **India** both now sit in the top 5 solar generators globally, alongside USA and Japan.
- In the **Global south**, the modular and distributed nature of renewables, as well as low costs and high generation potential, are driving faster electrification than ever before, which in turn brings opportunities for faster, cleaner economic development.

ENABLING POLICIES:

- **Effective system planning and regulatory frameworks** to enable rapid deployment, flexible storage and demand-side flexibility.
- **Minimal feed-in-tariffs** or contracts for difference to protect renewables from price volatility and provide a stable long-term investment climate (Ason and Dal Poz, 2024).
- **Improving grid flexibility and rapid deployment of storage capacity.**

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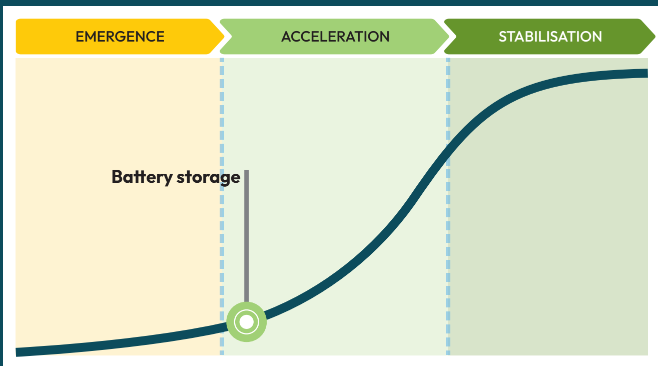
BATTERY STORAGE

Battery storage is essential to accelerate deployment of renewables by overcoming challenges of intermittent supply. **Global energy storage capacity must increase sixfold to 1,500 GW by 2050, of which 1,200 GW is expected to be provided by batteries** (IEA, 2024)



Progress:

Average price of lithium ion battery packs dropped to $115 USD/kWh in 2024, down 20% on the previous year and 84% lower than average cost in 2014, driving large increase in installed storage capacity (Figure 3.3.2). Globally, installed battery capacity nearly doubled from 86 GW in 2023 to 159 GW in 2024 (Ember, 2025).

Batteries can be installed both in utility scale systems (accounting for ~65% of installations), and in domestic or small-scale 'behind-the-meter' systems (~35%)(IEA, 2024).

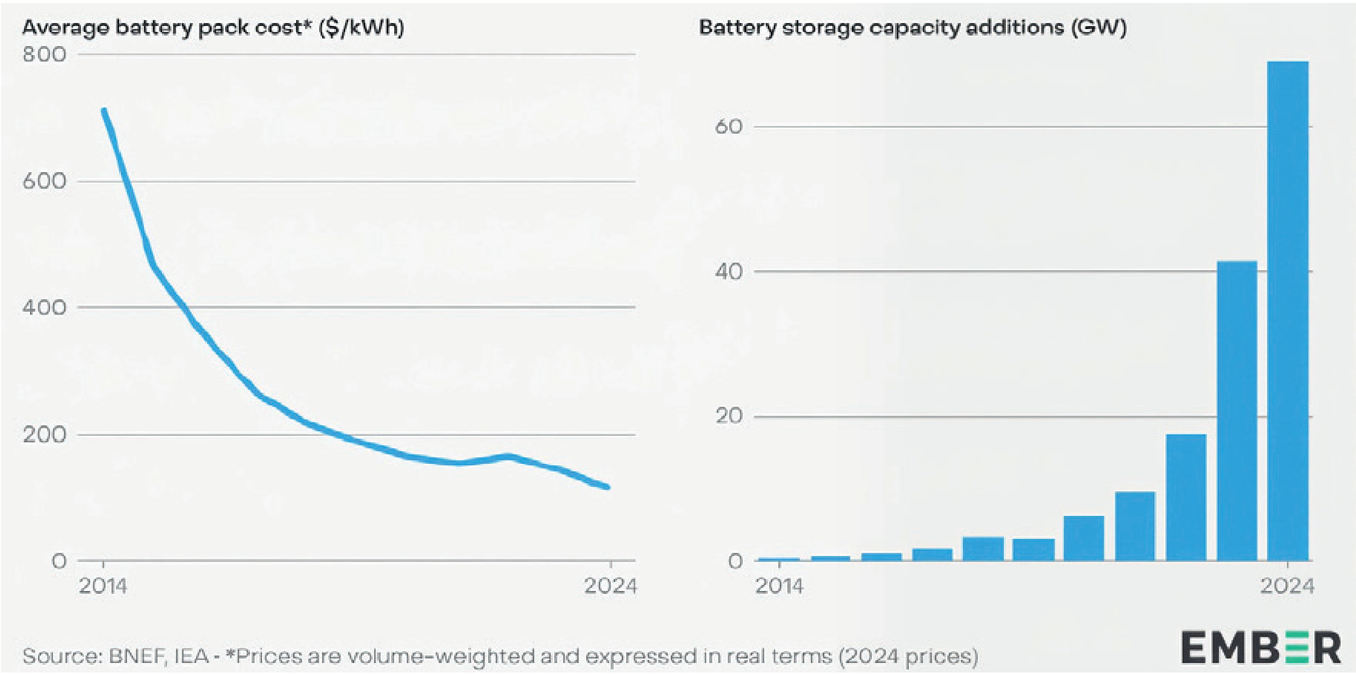


Figure 3.3.2: Battery storage installation has grown rapidly as battery prices have fallen (reproduced from Ember, 2025).

- **China dominates battery supply chains,** producing more than three quarters of batteries globally, and is also the world leader in battery storage installations, accounting for 55% of global capacity additions (23 GW) in 2023 (IEA, 2024). Provincial level mandates to pair battery storage with new solar pv and wind developments, as well as a growing market for commercial-scale behind-the-meter storage systems have been key drivers.
- The **USA** is the second largest market, with 8 GW added in 2023, a doubling year-on-year driven by market reforms, falling battery costs and domestic production, and an investment tax credit under the Inflation Reduction Act (IEA, 2024). **California** and **Texas** are significant leaders in battery storage. In 2024 batteries met nearly 20% of California's summertime daily peak loads, up from less than 2% in 2021 and significantly displacing gas generation (Ember, 2025).
- In the **EU** installations increased 70% in 2023 to 6 GW. Nearly 90% of capacity additions in the EU were behind-the-meter storage, mostly in **Germany** and **Italy** where high retail electricity prices and supportive policy incentivise pairing rooftop solar installations with battery storage. The **UK** is Europe's largest market for utility-scale batteries, adding over 1 GW in 2023 (IEA, 2024).
- **Australia, Japan** and **Korea** are also significant leaders in installations. **Chile** is the first country in Latin America to deploy battery storage at scale.
- Capacity growth is expected to broaden into new markets (e.g. in India and **sub-Saharan Africa**) with significant growth potential (IEA, 2024). Current installations in these markets are primarily used to back up unreliable grid connections (e.g. over three quarters of installations in **Nigeria**). Installations are expected in increase significantly as electrification efforts increase; over 80% people without access to electricity live in rural and remote areas where mini-grids and stand-alone systems powered by increasingly affordable solar pv offer the cheapest and most pragmatic solution for electrification.

BALANCING OR RESISTING CHANGE

- Lack of adequate **regulatory frameworks for battery storage** in many countries slows investment and deployment. Many countries lack appropriate remuneration schemes for battery storage or have other regulatory barriers to market access (IEA, 2024).
- **Slow deployment of smart-meters and slow modernisation of grid management systems**, especially in emerging and developing markets, slows deployment of battery storage.
- **Delays in obtaining planning consent and grid connections** are slowing deployment in many jurisdictions (IEA, 2024).
- **Consolidation of manufacturers and supply chains, especially in China**, may lead to reduced competition and slow price declines (IEA, 2025).
- Concerns about the **availability of critical materials and environmental impacts**
- **Risks and benefits do not always receive balanced media attention, leading to misinformation**, which can slow public acceptance and investment.

REINFORCING OR ENABLING CHANGE

- **Falling prices are driven by economies of scale, and learning by doing**, especially through the exponential growth of markets for battery electric vehicles (RMI, 2023). **Changes in battery chemistry** (e.g. increasing use of lithium iron phosphate, reducing need for nickel and cobalt) as well as improvements in design have played a significant role (IEA, 2025).
- **Falling prices have driven rapid rises in capacity additions** at a rate of 67% per year over the last decade.
- **Co-location with renewable power generation** can improve the business case for developing new utilities by enabling them to be more flexible in meeting demand. Policy to incentivise or mandate co-location is accelerating deployment in some regions.
- **Batteries can provide multiple services**, including **supporting grid-flexibility**, but also providing ancillary and back-up services and congestion management in transmission and distribution systems.
- **Flexible battery storage can enable domestic consumers to reduce energy costs** and increase benefits of rooftop solar installation.
- Low prices for critical minerals also contributed to lower costs last year.
- **Developing circular and recycling systems for critical minerals** can help keep prices stable and lower costs for producers and consumers. It also reduces harm from mining and can improve public support (RMI, 2024).

ENABLING POLICIES:

- **Mandates, targets or incentives for co-location** of battery storage with new solar and wind developments.
- **Contracts for differences** and other similar mechanisms (e.g. Australia's Capacity Investment Scheme) can provide more stable long-term revenue and lower barriers to investment.
- Support for creating **secure, sustainable and resilient supply chains for critical minerals.**
- **Feed-in-Tariffs, tax breaks, subsidies, low-interest loans** incentivise behind-the-meter installations.
- **Enabling behind-the-meter installations to participate in energy markets** creates benefits for the energy system (e.g. increasing flexibility) and opens additional revenue streams for domestic and small-scale commercial installations (as e.g. in the UK).

Sources:

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IEA (2024) Batteries and Secure Energy Transitions. International Energy Agency. Available at: https://www.iea.org/reports/batteries-and-secure-energy-transitions

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EA (2025) The battery industry has entered a new phase. International Energy Agency. Available at: https://www.iea.org/commentaries/the-battery-industry-has-entered-a-new-phase.

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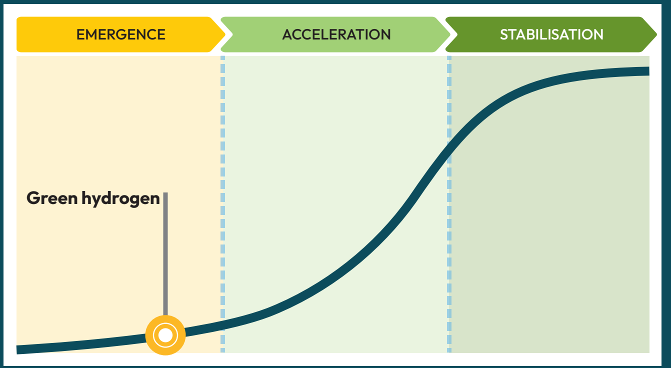
GREEN HYDROGEN

Green hydrogen from electrolysis powered by renewable energy could replace grey hydrogen in industrial uses including in chemicals industries, production of steel and cement and manufacture of ammonia for fertiliser. Replacing current global hydrogen production would **remove around 2% of global greenhouse gas emissions.**



Progress:

Green hydrogen production is growing, from 1.0 Mt per year in 2023 to potentially 49 Mt per year in 2030 based on announced projects, or more than half of current hydrogen use in the economy (~97 Mt per year) (IEA, 2024). Global installed electrolyser capacity was nine times larger in 2024 than 2021 (0.2-5.6 GW), and investment in electrolyser installation grew from 0.3 bn USD to 7 bn USD in the same period. Although modelling studies suggest that electricity will play a much larger role than H2 as the main sector-coupling driver for achieving deep CO2 emission cuts towards GHG neutrality, hydrogen might still play a key contribution to decarbonize specific market segments in which electrification is challenging or not yet commercially available, for example primary steel-making (van der Zwaan et al., 2025).

Although green hydrogen is currently more expensive than grey and blue, **it could become the cheapest form of hydrogen with continued government support**. Costs are expected to reduce and – subject to market uptake, electrolyser innovations and lower renewable energy costs – could be 66% lower by 2030 (IEA, 2024).

- **China** is the world's largest hydrogen producer and consumer, and has made green hydrogen a key element of its decarbonisation strategy.
- In **Brazil** green hydrogen is already cost-competitive with domestic fossil-fuel based hydrogen production under current policies (Vercoulen et al., 2025).
- **The USA, European Union, India, Japan, Germany** and other countries have set ambitious hydrogen production targets (IEA, 2024; RMI, 2025*a*, RMI 2025*b*). Net energy importers with strong renewable energy potential like **Chile, Morocco and Namibia** are also emerging as major players in the global green hydrogen market. Affordable green hydrogen could offer transformative industrialisation opportunities for emerging markets and developing economies.

BALANCING OR RESISTING CHANGE

- **Costs remain high**. Green hydrogen currently costs 2-3 times more than grey hydrogen. Significant interventions (e.g. carbon pricing combined with mandates) are likely necessary for green hydrogen to be economically competitive in the near- to mid-term (Vercoulen et al., 2025).
- **Thermodynamic constraints**: whereas solar plus batteries provides a huge energy efficiency saving when replacing fossil fuels, hydrogen production doesn't, limiting its uses (Johnson et al., 2025).
- **Lack of finance** for inexpensive renewable energy and infrastructure, especially in emerging markets and developing countries.
- **Storage and transportation challenges** due to relative bulk and safety risk. The high costs of storing and transporting hydrogen limit its usefulness in many potential applications (Johnson et al., 2025).
- Lack of **availability of critical materials** (e.g. iridium) for green hydrogen electrolysers if proton membrane technology continues to be used.
- **Lack of investor certainty** around projected hydrogen demand (OECD, 2024; McKinsey, 2024).

REINFORCING OR ENABLING CHANGE

- Green hydrogen electrolysers are becoming more **modular and standardised, enabling fast scaling** at low cost, with high learning rates of 18% cost reductions per doubling of output.
- **Plummeting costs of renewable energy** are also driving costs lower.
- With **policy support** and market uptake, learning-by-doing enables faster, more efficient production.
- Larger, **automated production facilities** could reduce costs by 80% in the longer term.
- **International cooperation on hydrogen storage and transportation standards** could reduce logistical barriers to scaling (Cordonnier and Saygin, 2022).
- Increasing **innovation and development of end-use applications** (particularly in transport and shipping) can help to expand markets.

ENABLING POLICIES
(ETC, 2021):

- The greatest opportunity to scale up green hydrogen quickly is to **create economies of scale for its use in sectors where it can replace grey hydrogen** – ammonia production for fertilisers, crude oil refining, and methanol production.
- **Mandates for green hydrogen in steel and ammonia production** are needed to crowd in private investment to build larger, standardised plants and green hydrogen hubs.
- **International coordination of policy** across industrial users of green hydrogen can accelerate learning and economies of scale.
- **Significant policy support through public investment and financial incentives** to increase the price of fossil fuels and lower the cost of renewable energy will help to reduce costs of green hydrogen production.
- **Elimination of fossil fuel subsidies and increased carbon pricing** can make green hydrogen more competitive.

Sources:

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Vercoulen, P. et al. (2025) EEIST: Can demand for green fertiliser accelerate electrolytic hydrogen supply? Available at: https://eeist.co.uk/eeist-reports/can-demand-for-green-fertiliser-accelerate-electrolytic-hydrogen-supply/.

van der Zwaan, B. et al. (2025) 'Electricity- and hydrogen-driven energy system sector-coupling in net-zero CO2 emission pathways', Nature Communications, 16(1), p. 1368. Available at: https://doi.org/10.1038/s41467-025-56365-0

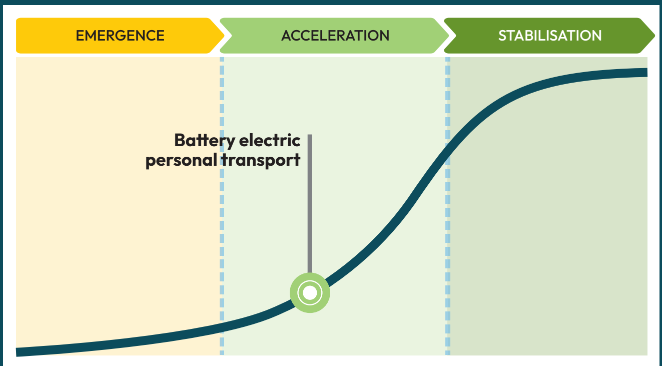
ENERGY & POWER: **DEMAND**

Electrifying energy demand is essential for renewables to replace fossil fuels. Since around 60% of primary energy is used as fossil fuels (mainly oil and gas) in transport, buildings, and industry, electrifying these sectors is crucial to cut greenhouse gas emissions and strengthen energy security (Ember, 2025). In hard to electrify sectors such as shipping and aviation, opportunities exist for the manufacture of green fuels using renewable electricity.

Ember (2025) The electrification imperative. Ember. Available at: https://ember-energy.org/latest-insights/the-electrification-imperative.

BATTERY ELECTRIC PERSONAL TRANSPORT

Electrifying cars and 2 and 3 wheeled transport could remove **9% of current global greenhouse gas emissions** and improve air quality in cities.



Progress:

Sales of battery electric vehicles continue to increase rapidly in key markets, following S-curves driven by cost declines and performance improvements, with deployment spilling over into other markets as a result (Figure 3.3.3). More than 20% of all new cars sold globally in 2024 were battery electric vehicles (BEVs), a 25% increase on 2023 (IEA 2025). The global stock of BEVs has reached almost 58 million, about 4% of the total stock, displacing over 1 million barrels per day of oil consumption. The global average price of BEVs fell in 2024, driven by falling battery prices, but a purchase price gap with conventional vehicles remained in many markets outside China. Public charging stations have doubled in the last 2 years, keeping pace with EV sales. Strong sales growth looks set to continue in 2025.

2- and 3-wheeled vehicles which provide essential personal and commercial transport in cities, and particularly in the global South, are furthest ahead in electrification: in 2024 38% of 2-wheeler sales were electric; in the smaller 3-wheeler sector, this grew to 80% (BNEF 2025). In both sectors cheaper lead batteries are still popular, but lithium-ion vehicles are gaining traction.

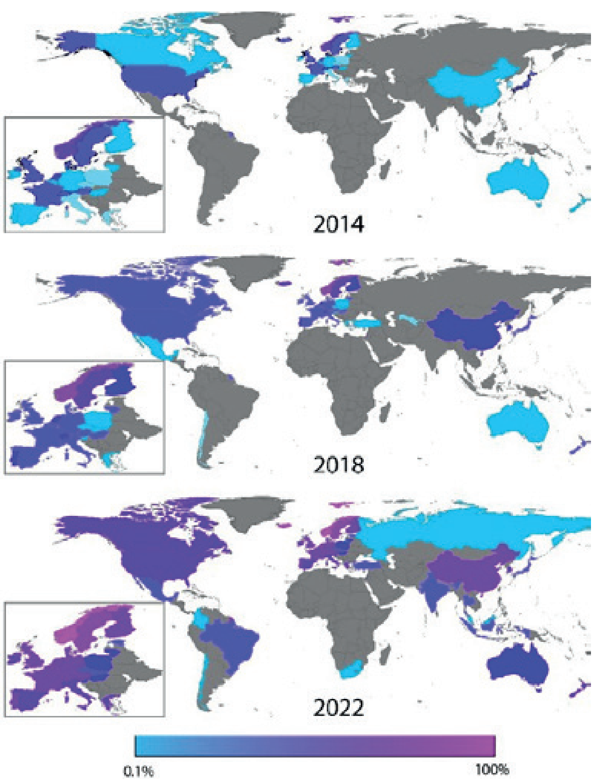


Figure 3.3.3: BEV adoption (per cent of market share) and spillovers from major markets into peripheral and developing markets from 2014-2022 (adapted from Mercure et al., 2025).

- **China**: roughly 1 in 10 cars is now electric (including BEV and hybrid vehicles). In 2024 roughly 11 million electric vehicles were purchased in China (of which more than 6 million were BEVs), more than all global sales in 2022, and electric vehicles have overtaken conventional cars with more than 50% market share since July 2024. The median purchase price of BEVs was around USD 24,000, about USD 700 less than for an internal combustion engine vehicle (ICEV). China accounted for more than 70% of global production in 2024, largely for the domestic market, but numerous Chinese car makers have recently announced foreign direct investment plans signalling a ramping up of overseas production to supply other markets (IEA, 2025).
- **Norway**: with near total electrification of car sales (BEVs 88% of market share in 2024), Norway has passed through the acceleration phase and is now in the stabilisation phase of the S-curve. Norway is now imposing increasingly stringent taxes on conventional cars and hybrid vehicles, aiming to reach 100% BEV market share in 2025. This tipping point in sales will still take several years to convert the whole of Norway's car fleet to electric vehicles; 1 in 3 cars currently in use in Norway was electric in 2024 (IEA, 2025).
- **UK**: BEV sales reached a nearly 20% market share in 2024, driven in part by the introduction of progressively stringent targets under the new Vehicle Emissions Trading Scheme. Including hybrid vehicles, electric cars took nearly 30% market share. Charging infrastructure development has not kept pace however, with the number of vehicles per charging station increasing in 2024 (IEA, 2025).
- **EU**: electric car sales remained around 20% of market share in the EU as a whole for 2024, as policy support was weakened or phased out in key markets including **France** and **Germany**, leading to stalling or declining sales, though initial reports suggest that growth is returning in 2025 (Rueters 2025). Growth in sales continued in 14 out of 27 member states however, including in **Denmark**, where sales of electric vehicles increased 10 percentage points to reach 56% market share. Initial reports suggest
- **USA**: Electric car sales increased to more than 10% market share in 2024, but the rate of growth slowed significantly from 2023. However, this came against a backdrop of stagnating sales in conventional cars, suggesting that electric car sales slightly boosted the overall market (IEA 2025).
- **Emerging markets**: electric vehicle sales doubled or more than doubled in many markets in **Asia**, **Africa**, and **Latin America** in 2024, albeit from low baselines compared to leading markets. **Brazil** is a notable leader in Latin America. In Asia, **Thailand, Malaysia , Indonesia** and **Vietnam** are all seeing rapid growth in sales, driven in part by reductions or exemptions on import taxes for electric vehicles for companies that invest in domestic production. In Africa, **Morocco** and **Egypt** have seen growth in sales, while Ethiopia's ban on imports of petrol and diesel cars has reportedly driven rapid deployment of 100,000 electric vehicles, though it appears that deployment of charging infrastructure and maintenance and repair capacity are struggling to keep pace. In India, levelised costs of 3-wheelers are lower than their ICEV equivalent. With subsidies, payback times are roughly 2 years

BALANCING OR RESISTING CHANGE

- **Purchase prices for BEVs remain higher than for conventional vehicles in most markets**, with limited availability of affordable car models. The same is true for 2 and 3 wheelers, for instance purchase price of 3 wheelers is on average 55% higher than fossil fueled alternatives in India. As 2- and 3-wheelers are popular in less affluent countries, this can pose an important barrier for uptake.
- Some important markets are phasing out or **weakening supportive policies**, including subsidies and tax incentives, including France, Germany and USA.
- **Delaying or weakening mandates** for the transition to electric vehicles creates uncertainty, slowing investment and innovation.
- **Tariffs and trade restrictions are slowing trade in BEVs**, especially reducing access to markets in the UE, USA and elsewhere for China, which manufactures the highest numbers, and lowest cost, BEVs.
    - » A longer-term effect of this is to drive accelerated investment by Chinese car makers in manufacturing capacity in other markets, including EU, South East Asia and Brazil, which may ultimately accelerate production and sales. Chinese overseas manufacturing capacity is expected to double to over 4.3 million vehicles per year by 2026 .
- **Vehicle oversizing increases electricity demand**, making decarbonising electricity more difficult, and may reduce EV support due to greater risks to pedestrians from heavier cars (ACEEE , 2024).
- **Public perceptions remain mixed** and susceptible to misinformation and negative portrayals of BEVs (e.g. on demand, performance, price, environmental and other impacts) in the media (ECIU, 2025).

REINFORCING OR ENABLING CHANGE

- **Falling prices and improving performance**, especially in batteries, continues to make BEVs more attractive to consumers. Cost reductions driven by economies of scale and learning by doing in major markets are making BEVs accessible in emerging markets. In most emerging markets in 2024, the purchase price of the cheapest electric vehicle was lower than the average price of an ICEV. 2 and 3 wheeled vehicles are seeing rapid innovation and accelerated learning as a result of their short lifetimes (~10 years).
- **Increasing model diversity** enables BEVs to compete in more market niches. The number of available models increased 15% year on year to reach 785 in 2024, passing 50% of the combined number of models of ICE and hybrid vehicles. Based on data for announced models, BEV models will reach 70% of combined ICE and hybrid models by 2027. In China, the number of electric models is already greater than the number of ICE and hybrid models, and the price distribution of BEVs closely matches that of ICEVs, with more than half of available electric models below USD 30,000.
- **Market competition and economies of scale in car manufacture** are also leading to price reductions.
- Tax exemptions or reductions (e.g. VAT, import taxes), or trade-in schemes can **reduce purchase and operating costs to make BEVs competitive with conventional cars**. In many countries this is being paired with incentives or requirements for importers to invest in domestic production facilities, boosting investment, jobs and skills as a co-benefit.

ENABLING POLICIES:

- **Emergence phase**: for countries at the beginning of the S-curve, boosting investment in R&D, reducing import costs, investment in building and scaling charging infrastructure and public procurement of BEVs can help to drive initial market growth.
- **Acceleration phase**: Reducing purchase and operating costs through tax exemptions and subsidies, alongside expanding charging infrastructure and support services, helps sustain and boost BEV growth. In countries with strong vehicle manufacturing industries, support with transition costs and investment in manufacturing will likely be key for public support.
- **Stabilisation phase**: In countries in the later phase of transition, increasing taxes on conventional and hybrid vehicles can help stabilise BEV ownership as the new status quo. Purchase subsidies and trade-in schemes can help offset the purchase price difference in markets where BEVs remain more expensive.
- **At city scales**, low-emissions zones and other local restrictions can drive BEV adoption as well as improving public health and reducing congestion.

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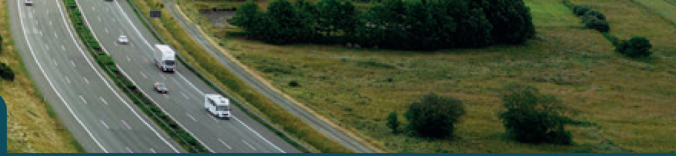
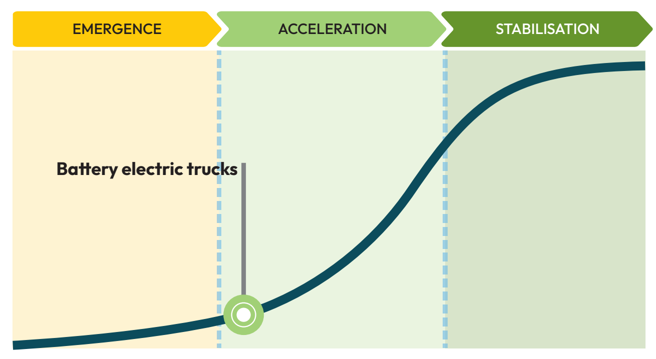


BATTERY ELECTRIC ROAD FREIGHT

Electrifying road freight could **remove up to 6% of global greenhouse gas emissions.**



Progress:

Global sales of full electric trucks are growing rapidly, increasing 35% year on year from 2022 to 2023 to reach 0.9% of global market share (Akther et al., 2025). More than 400 models of battery electric truck are available, up from fewer than 70 in 2020, indicating increasing diversity and ability to fulfil different applications and niches. Lifetime total cost of ownership (TCO) has either passed or is rapidly approaching parity with diesel and petrol vehicles in many markets.

- **China** represented over 80% of global sales in 2024 (IEA, 2025). Rapid development and innovation in batteries and trucks, subsidies, procurement requirements and clean air zones in cities have driven deployment and cost reductions.
- **EU**: second behind China in deployment, driven largely by stringent emission standards.
- **India**: Strong progress in electrifying 2- and 3-wheeled vehicles often used for last-mile delivery, with >50% of sales of 3 wheelers electric in 2022. In this sector, the cost of zero-emission vehicles (ZEVs) is already substantially lower than alternatives. For medium- and heavy-duty vehicles, higher purchase prices offer a significant barrier to adoption.

BALANCING OR RESISTING CHANGE

- Although lifetime cost of ownership is lower for ZEVs in many markets, **purchase costs remain high** (1.5-2 times the cost of petrol and diesel trucks) which can present a barrier to transition for smaller companies who are less able to make large capital investments.
- **Performance of ZEVs is still catching up with petrol and diesel trucks.** Long charging times, lower payloads relative to petrol and diesel vehicles, and lack of supporting infrastructure reduce attractiveness and performance of ZEVs.

REINFORCING OR ENABLING CHANGE

- **Advances in light road transport** have significantly improved battery performance, lowered costs, and driven development of charging infrastructure.
- **Operating costs for battery electric trucks are significantly lower** than for petrol and diesel trucks in many markets:
- For **medium-duty ZEVs**, lifetime cost of ownership is likely already lower than that of petrol and diesel trucks in China, roughly equal in the USA and only slightly higher than diesel trucks in India.
- For **heavy-duty ZEVs**, lifetime costs of ownership are lower than for petrol and diesel trucks in India and China, and slightly higher in USA and Germany.
- 33 countries are part of the Global Memorandum of Understanding on Zero-Emission Medium- and Heavy-Duty Vehicles, committed to reaching a 30% ZEV sales share sales by 2030, and 100% by 2040.

ENABLING POLICIES:

- **Regulatory policies** including fleet-wide emissions reduction standards and especially ZEV mandates are likely to achieve the fastest transition. City scale zero-emission or low-emission zones can also be effective at growing the market for ZEVs.
- **Subsidy can enable capital-constrained businesses to transition their fleets** and benefit from the lower operating costs of battery operated trucks (Mission Possible Partnership, 2022).
- **International cooperation among the largest markets** (especially China and EU, but also India, Canada and supportive US states) for zero-emission freight can significantly bring forward a tipping point of price-parity in total cost of ownership.
- **Well aligned policy can incentivise supply chain optimisation** that takes charging infrastructure and schedule into account. For example, mandated rest periods, like the 45 minutes required in the EU, can reduce the opportunity cost of longer charging times en route, enabling drivers to add 150–400km of driving range while resting depending on charger capacity.
- **Policy support for battery swapping** makes green trucking more attractive logistically and cost-wise.

Sources:

Akther, A. et al. (2025) EEIST: Driving the Transition to Zero-Emission Trucks. Available at: https://eeist.co.uk/eeist-reports/driving-the-transition-to-zero-emission-trucks/

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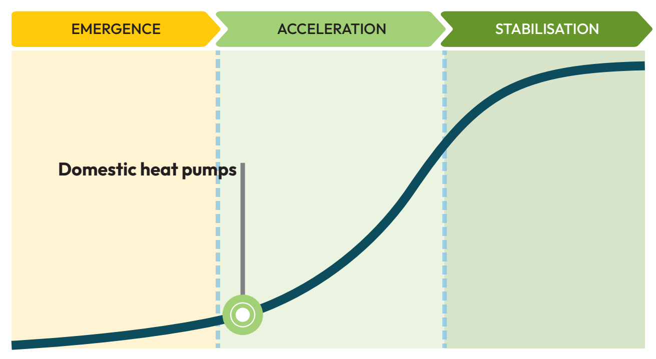
DOMESTIC HEAT PUMPS

Electrifying home heating could **remove 6% of global greenhouse gas emissions.**



Progress:

Progress: Globally, around 10% of space heating was met by heat pumps in 2021 but the rate of installation is growing rapidly (15% growth in 2021) (IEA 2022). Heat pumps are already less emissions-intensive than fossil fuel boilers in almost all countries. As the electricity supply is decarbonised, this will continue to increase. In some countries, heat pumps are already the largest heating source.

- In **Norway**, 60% of buildings are equipped with heat pumps.
- **China** is the largest market for new sales, while the **USA** has the largest number of residential home installations (IEA, 2022).
- In the **USA**, heat pumps outsold gas furnaces by 30% in 2024, the largest gap ever recorded (IEA, 2025; Knobloch et al., 2020).
- **Total cost of ownership** of heatpumps is already lower than for a fossil fuel boiler in some countries, including **Denmark** and **Italy**.

BALANCING OR RESISTING CHANGE

- **High upfront cost** of purchase and installation
- **Higher running costs where there is a high electricity-to-gas price ratio**, often due to subsidy policies.
- Installers' **perception of a lack of heat pump demand from households.**
- **Low rate of training** of new heat pump installers and engineers.
- **A long installation timeline compared to a replacement boiler** increases challenges for 'distress purchases'.
- **Misinformation in the media**, promoted by vested interests, has in some regions created a negative narrative environment and increased uncertainty
- Heat pumps reduce total domestic energy consumption, but total electricity consumption will significantly increase, requiring **significant investment in electricity infrastructure, flexibility, and storage.**

REINFORCING OR ENABLING CHANGE

- **Increasing returns to adoption:** economies of scale and learning curves. The more heat pumps deployed, the lower their purchase price and the better their performance.
- Greater use of heat pumps r**educes dependence on imported fossil fuels**, improving the balance of payments and domestic energy security.
- Heat pump running **costs are typically lower than gas boilers**, reducing exposure to gas price spikes.
- A **stable regulatory environment** with long-term targets (e.g. phase-out dates) increases industry and customer confidence in the transition.
- **Improved building insulation reduces energy demand**, reducing strain on the grid and raising the efficiency of heat pumps.
- **Peer effects of technology adoption** have been observed for heat pumps. As more households in a community adopt, it supports others to adopt, particularly through word-of-mouth dissemination.

ENABLING POLICIES:

- **Mandates on the sale and installation of heat pumps**, regulations for new homes, and the **phase-out of fossil fuel boilers** are likely the most cost-effective measures to increase the market share of domestic heat pumps.
- Rebalance taxes and levies on electricity prices to **reduce the electricity-to-gas price ratio**, such that the efficiency gains of heat pumps result in running cost savings over fossil fuel boilers.
- Interventions for upfront cost: Low- or zero-interest loan schemes to **help households afford the higher upfront costs of heat pumps**. Boiler upgrade schemes offering grants to replace fossil fuel boilers with heat pumps.
- Training for heat pump installers, Incentive schemes and streamlining of certification processes to **build a certified installer base.**
- Subscription-based **"heat as a service" schemes.**
- **Align international policy action in the largest markets** for heating to enable faster cost declines through learning curves and economies of scale.
- **International standards** of heat pump performance requirements help reduce costs by lowering compliance costs for manufacturers.
- **Investing in digital technologies** that allow heat storage systems to operate when electricity demand and prices are low.
- **Public engagement campaigns** and 'one-stop shops' that streamline the customer journey and provide trustworthy information.
- **Customer protection and industry standards** will increase consumer trust in the quality of heat pump installations and increase heating efficiency.

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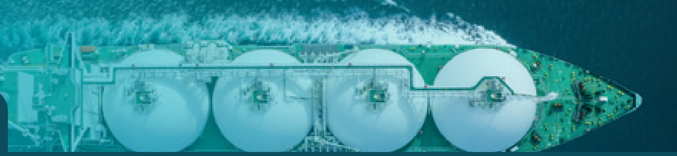
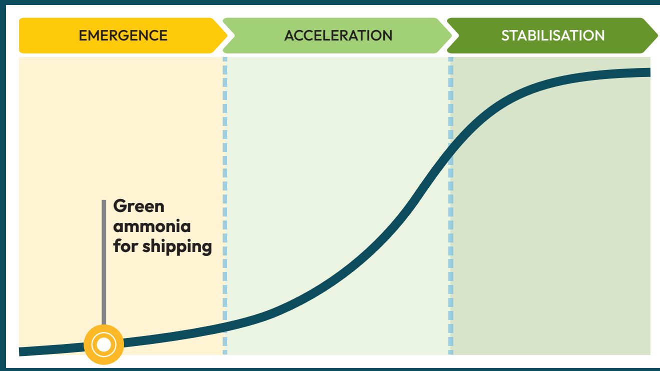


GREEN AMMONIA FOR FERTILIZER AND SHIPPING FUEL

Use of green ammonia to manufacture fertiliser could **remove 2% of global greenhouse gas emissions**, and could lower costs sufficiently to make it viable as a fuel in long-range shipping, **removing a further 2% of global greenhouse gas emissions** and reducing black carbon emissions.



Progress:

Cost effective production of green ammonia by reacting green hydrogen with nitrogen separated from air could accelerate its use in fertilisers for agriculture (70% of ammonia use), industrial applications including plastics, explosives, and synthetic fibres, and sustainable fuels for long-range shipping (OECD, 2025).

Green hydrogen for ammonia production can only be cost-competitive in regions with plentiful, low-cost renewable electricity supply, and **scaling production is dependent on continuing rapid deployment of renewables**. Forecasts of the compound annual growth rate for green ammonia range from 70% to 88%, driven by environmental concern, strong government support, advances in green hydrogen electrolyser technology, and demand for sustainable fertilisers and alternative fuels. **Cost parity** of green ammonia with conventional ammonia is expected in most markets from 2034 (BloombergNEF, 2024), but will require considerable policy support to do so. Reaching cost-parity for fertiliser production (currently the largest market), can enable further cost reductions that increase competitiveness for other uses including shipping fuels.

- The **Asia-Pacific** region is the leading producer of green ammonia, led by China.
- **Australia** and **India** are emerging as key players due to their renewable energy potential and strong government support.
- **Brazil's** supportive policy environment for green hydrogen production could enable it to become self-sufficient in green ammonia fertilisers for it's agricultural industry (Vercoulen et al., 2025).

In 2025 the **International Maritime Organisation published the first interim safety guidelines for use of ammonia as a shipping fuel** (IMO, 2025), setting in place a risk-assessment and management framework to facilitate early adopters. As of September 2025 **77 ammonia-ready vessels are operational**, and a further 154 ammonia-fueled vessels and 261 ammonia-ready vessels have been ordered and announced (Ammonia Energy Association, 2025). The first operational vessels are small-scale supply ships and tug boats, with ammonia carriers and bulk carriers among the vessels ordered.

BALANCING OR RESISTING CHANGE

- **Current hydrogen policies are insufficient** to start the large-scale deployment of electrolytic hydrogen production globally.
- **Subsidies for fossil fuels and low carbon prices** make it difficult for green ammonia to achieve cost parity.
- **Low-replacement rates of existing plant and infrastructure**, and sunk costs of investments in hydrogen and ammonia production from fossil fuels, slow investment in new infrastructure.

REINFORCING OR ENABLING CHANGE

- **Falling costs and rapid deployment of renewable energy** generation and storage reduce the cost of green hydrogen more rapidly than improvements in electrolyser technology (Vercoulen et al., 2025).
- **Economies of scale and learning curves:** 18% cost reductions per doubling of output have been experienced for hydrogen electrolysers (IRENA, 2020)
- **Further enabling policies** (e.g. mandates and price mechanisms) are likely to be necessary to make green ammonia competitive in the near to mid-term (Vercoulen et al., 2025).

ENABLING POLICIES:

- Small group coalition of leading countries could introduce a **blending mandate of 25% green ammonia in fertiliser production** (Meldrum et al., 2023)
- Meet the **International Maritime Organisation's target** to achieve at least 5% utilisation of zero-emission fuels by 2030.
- **Create a clean hydrogen strategy** (as in Japan, South Korea, China, USA, EU, India, Australia and elsewhere).
- **Policies guaranteeing long-term low renewable energy costs.**
- **Public investment in green hydrogen electrolysers and infrastructure** (e.g., ammonia bunkering in ports) (RMI, 2024).
- **Eliminate fossil fuel subsidies and increase carbon price** (Lee and Saygin, 2023).

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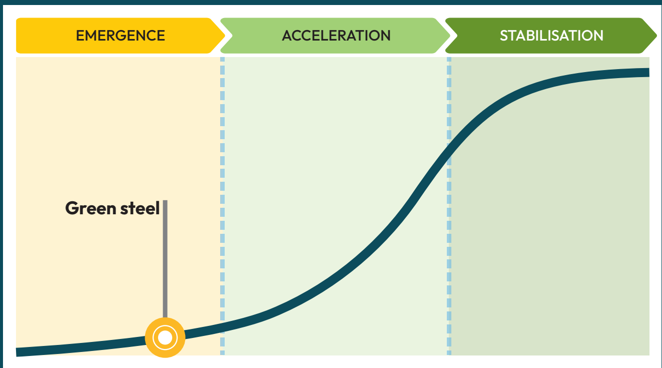
GREEN STEEL PRODUCTION

Transitioning to green steel production could **remove 7% of global greenhouse gas emissions**



Progress:

Hydrogen-based DRI combined with electric arc furnace technology is rapidly emerging as a key pathway for green steel production, while major steel-producing countries and companies are setting ambitious targets for low- and zero-carbon innovation and investment.

However, the rate of deployment is still slow, with only **11 full scale green hydrogen DRI steel plants planned to be operational by 2030** (Mission Possible Partnership, 2022; Stockholm Environment Institute, 2025).

BALANCING OR RESISTING CHANGE

- **Green steel production costs are higher** than coal-fired blast furnaces
- **Slow replacement rate** of steel production facilities
- **Low quality of iron ore.** Currently, only 13% of iron ore shipped for processing meets the required quality for DRI steelmaking.
- **Job losses** associated with phasing out old infrastructure.

REINFORCING OR ENABLING CHANGE

- Green hydrogen DRI has the largest GHG emissions mitigation potential and could generate reinforcing feedbacks through learning curves and economies of scale. As more green hydrogen electrolysers come into operation, **cost reductions of up to 18% per doubling of output are possible.**
- A positive tipping point becomes more likely once **at least 6% of steel plants adopt DRI** technology (approximately 25 plants).

ENABLING POLICIES:

- Policy instruments, including measures to **lower the unit price of green hydrogen and the unit price of renewable energy.**
- Financial instruments to **de-risk investments in emerging markets and developing economies.**
- **Mandates for phasing in green hydrogen DRI technology and phasing our blast furnaces** are likely to offer the fastest and most cost-efficient decarbonisation pathway for steel production.
- **Require green steel for publicly funded construction projects.**
- **Small group coalitions of leading steel producers** (eg China, India, Japan, USA) **coordinate policies** and overcome first-mover risks (Meldrum et al., 2023).
- **Strategic planning and support for workers** who face the risk of job losses during the transition.

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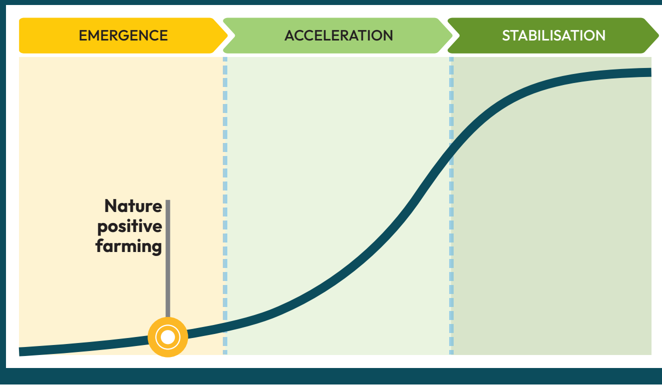
FOOD, LAND USE & NATURE

Food production and other land uses are responsible for up to a third of global greenhouse gas emissions, are the largest driver of nature and biodiversity loss, and pose direct threats to critical ecosystems in danger of tipping points (see 4.1 Amazon Case Study and 4.3 Coral Reefs Case Study). Urgent and complementary actions are required to end deforestation, shift to nature positive farming, reduce food waste and shift food demand in overconsuming societies. These are discussed further in GTPR2023, and Chapter 3.5

SHIFT TO NATURE POSITIVE AGRICULTURE

Shifting to nature positive farming could **remove CO2 from the atmosphere, increase soil health** and **build resilience to extreme weather.** System-wide adoption is likely dependent on other shifts in food waste, food demand and supply chain reforms.



Progress:

Absolute global numbers are difficult to report, however a number of initiatives and practices demonstrate effective scaling in different contexts.

- 'Conservation agriculture' (CA), promoted by the UN Food and Agriculture Organisation, has scaled at a rate of roughly 10 M ha per year, almost doubling from 107 Mha in 36 countries in 2008/9 to 205 M ha in 102 countries in 2018/19, roughly 15% of global cropland (Kassam et al 2022).
- Between 2000 and 2023, the global share of organic agricultural land (including crops and pasture) rose from 14.9 M ha to 98.9 M ha farmed by 4.3m farmers in 188 countries (2.1% of total global farmland) (Trávníček, et al. 2025). The global organic food market has grown to over USD $136bn in the same time, with the largest markets in USA, Germany and China. 22 countries have 10% or more of their agricultural land under organic management (e.g. Austria at 27%).
- Many smaller scale initiatives have scaled effectively where they offer direct and clear benefits to farmers, e.g. diversified incomes, lower input costs, improved soil health and other synergistic ecological and economic and/or social outcomes.
- The Danish Green Tripartite Agreement passed into law in June 2024. This is an accord between the Danish government, agricultural sector, and environmental groups to achieve climate, nature, and water quality targets through land-use changes and the world's first carbon tax on agriculture (with revenues directed back into agriculture to fund climate and nature positive solutions).

BALANCING OR RESISTING CHANGE

- **Policy and public/private investment lock-ins**: Agricultural policy and incentive structures often prioritise productivity, low food prices, and technology-led solutions at the expense of environmental sustainability (Zhang and Drury 2024).
- **Transition costs for farmers**: Moving to nature positive practices may require capital investment for new equipment, certification or other expenses, and may incur other costs (labour, time, foregone yield). Farmers may need to invest in acquiring **new skills and capacity** to learn new methods of production and access new markets (including payments for ecosystem services and certification).
- **Yield penalty**: In some systems, switching to nature positive farming may incur a yield penalty. In some cases this may be a temporary dip in productivity, leading to long-term neutral or net positive impacts (Pathania et al. 2024).
- **Network effects**: Existing networks of farm advisers, agronomists, sales reps, financial advisers can create strong balancing feedbacks that maintain the system status quo. Peers and families may also have cultural and social expectations at odds with nature positive farming practices (Coon et al. 2025, Pathania et al. 2024)
- **Land Access**: Insecure tenure discourages long-term planning and investment (in equipment or natural infrastructure, such as tree planting as part of agroforestry). (Olabanji and Chitakira, 2025, Pathania et al. 2024).
- **Conflicting and confusing labelling and standards** can create confusion among consumers or be appropriated as marketing tools or 'greenwashing' (Wilson, Hendrickson, and Myers 2024, Bless, 2025)

REINFORCING OR ENABLING CHANGE

- **Policy, subsidies and incentives:** clear policy goals supported by effective incentives or subsidies help to make alternative farming models economically attractive and overcome transition costs.
- Access to **markets for new or premium products and/or ecosystem services, including carbon sequestration**, can similarly provide economic incentives and drive adoption (e.g. Benjamin and Sauer, 2018). **Valuing natural capital** in farming landscapes can substantially alter the balance sheets for farmers, incentivising investment in resilient and healthy agroecosystems (Alexanderson, Luke, and Lloyd 2024).
- **Lower input costs** can also be an incentive for farmers.
- **Effective labelling and standards, and access to certification.**
- **Concentrated supply chains** can offer more leverage for particular actors (traders, manufacturers, retailers etc.) to set standards, influence farmers and support them to transition to sustainable practices (e.g. Amazon Soy Moratorium (Box 3.5.1), Better Cotton Initiative, and other sector specific initiatives).
- **Increasing ecological and economic resilience**: Restoring ecosystem service provision (e.g. soil health, moisture management), lowering input costs and diversifying farm revenue (e.g. through payments for ecosystem services, mixed cropping etc.) can enhance economic outcomes and provide resilience to extreme weather events and crop failures, providing incentive for vulnerable farmers to transition.
- **Social contagion** among farmers can drive diffusion of nature positive practices among farmers in many contexts (Läpple and Kelley 2013, Padel 2001, Wollni 2014).
- **Network effects** and **information cascades** can also drive change in the networks of farm advisers, agronomists, financial advisers and agricultural training centres that strongly influence decision making among farmers.

ENABLING POLICIES:

- **Policy to facilitate financial benefits, and offset transition costs**; including subsidy and incentives, and markets for ecosystem service provision (Baker et al., 2025, Hilmi et al., 2024)
- **Set clear, measurable targets** through design of metrics and monitoring frameworks (Baker et al., 2025, HLPE, 2019)
- **Design and implement schemes at landscape scale** (Baker et al., 2025, HLPE, 2019)
- **Targeted and context specific interventions** are more effective at triggering widespread uptake (Kassam et al 2022, Funke and Munyaradzi, 2025). Policy design benefits from **participatory approaches engaging with farmers**, recognising them as crucial agents of change to facilitate collaboration and cooperation (Baker et al., 2025).

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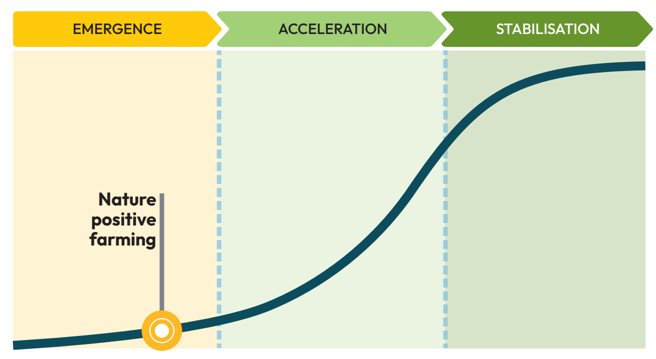
ADOPTING SUSTAINABLE DIETS

Could remove up to **17% of global greenhouse gas emissions** from the livestock sector. Even small reductions can have powerful impacts for **reducing threats in critical ecosystems.**



Progress:

Progress: Meat consumption globally has continued to rise due to population growth and increasing incomes. **But in some high income countries meat eating has decoupled from economic growth** (including UK, USA, Canada, Australia, Saudi Arabia, New Zealand, Switzerland, Israel) and in some cases has begun to fall (Whitton et al 2021, Stewart et al 2021). Correspondingly, the number of people identifying as 'flexitarian', 'vegetarian' and 'vegan' has increased in many countries, often driven by overlapping concerns around health, environmental impacts and ethics of overconsumption of meat (Dagevos, 2021; Rosenfeld et al., 2020). In the **UK**, vegetarian food orders at quick-service restaurants increased by 64% and vegan food by 56% from 2023-2024 (Good Food Institute, 2024). If the 60% of the world's population who currently overconsume were to adopt sustainable diets, they could more than offset the approximately 15% increase in global GHG emissions associated with undernourished countries moving towards healthier diets (Li et al 2024).

Plant-based alternatives to livestock products - seen as an important enabler of diet shifts in overconsuming countries (Meldrum et al., 2023) - have shown strong growth in leading markets over the last decade, with global sales rising from $18bn USD in 2015 to $29bn in 2024, with sales of plant-based meats growing faster than milk alternatives and other products (Good Food Institute, 2024). However, sales of these products have slowed in recent years with some regions (including USA) experiencing consecutive years of sales declines. Many of these **products do not yet meet consumers' expectations on taste or price**, and Meat alternatives were between **24-115% more expensive** than the meat benchmark across European countries in 2023 (Siegrist 2024). Consumer concerns over nutrition and sustainability are also slowing sales. 'New-generation' processed plant-based alternatives tend to contain more salt and sugar than processed meat products, but are also richer in fibre and lower in calories and saturated fat (Food Foundation 2024).

BALANCING OR RESISTING CHANGE

- **Existing policy and subsidies** skewed to maintaining livestock production and other unsustainable models of production and consumption:
  - In the EU 4x as much farming subsidy goes into animal products as plant ones. EU cattle farmers get >50% of income directly from subsidy. The EU spends almost 2x as much promoting meat and dairy products as fruit and vegetables. VAT on plant-based milk is higher than on dairy milk in several European countries.
  - Currently most countries have food based dietary guidelines (FBDGs) with significant environmental impacts (Springman, 2020) and only 38 countries explicitly reference environmental sustainability in their FBDGs (Aguirre-Sánchez et al., 2023)
- **Vested interests** in livestock production are a powerful lobbying group: The meat and dairy industry spend 190x more on lobbying than the alternative protein industry in the USA (and 3x more in the EU) (Vallone and Lambin, 2023). In Europe they have undertaken litigation to rule that plant-based milk alternatives cannot be called 'milk'.
- **Low public investment in alternatives:** £33m invested in alternative proteins in the EU and USA combined for 2014-2020, versus £35bn supporting meat and dairy production (Vallone and Lambin, 2023). UK spending on a flagship healthy eating campaign (£5.2m per year) is dwarfed by annual advertising of unhealthy products (£143m per year).
- **Institutional support is lacking** in many jurisdictions where national governments have rejected recommendations that would support changing diets, or actively stymied alternative proteins (e.g. Italy backed a ban on cultured meat). FAO has failed to recommend reducing livestock and dairy consumption.
- **Livestock products retain strong cultural value** in many countries.
- **Infrastructural and institutional incumbencies** in food supply chains, from farm practices, skills and machinery to supermarkets present barriers to systemic change.

REINFORCING OR ENABLING CHANGE

- **Social contagion:** Social networks and expectations strongly influence dietary choices and norms (Higgs, 2015). More plant-based meals are consumed by those whose family and friends exhibit the same preference (Sharps et al., 2021), and seeing others consume a more sustainable option in a restaurant encourages uptake (Salmivaara et al., 2021).
- **Reinforcement through nudging and choice architecture:** When more meat-free options are available, people eat less meat, e.g. doubling the proportion of vegetarian meals on a menu increases vegetarian sales by 41-79% (Garnett et al., 2019). Strong messaging on co-benefits for health may also positively affect consumer choices.
- **Policy feedback to consumers:** Politically acceptable policies (e.g. changing dietary guidelines in Denmark, Norway, Germany, Canada, New Zealand, Switzerland) can raise awareness and shift social norms and behaviours, increasing public support for further interventions (Fesenfeld and Sun, 2023).
- **Increasing returns to adoption** help increase the quality, diversity and affordability of plant-based meat alternatives, e.g. plant-based milks, plant-based meat alternatives, precision fermentation, sustainable aquaculture production. It is worth noting, however, that traditional foods like fermented soybean products (tofu, tempeh etc.) other pulses etc. are already available and readily compete with meat products.
- **Learning-by-consuming:** A positive experience of eating plant-based meat encourages further consumption (Fesenfeld et al., 2023).

ENABLING POLICIES:

- **Introduce dietary guidelines that are compatible with the Paris agreement, the CBD and public health goals.**
- **Innovation and investment to improve the attractiveness of plant-based alternatives** in terms of taste, freshness and nutritional value.
- Phase-in of policies including **public food procurement, mandates, taxes and subsidies in favour of plant-based food supply and demand.**
- **Support for farmers to transition to alternative business models** and nature-based solutions, including through growing markets for provision of ecosystem services.
- **A holistic, cross-departmental and cross societal approach to food/agriculture/land-use policy and planning**, as seen in the Danish Green Tripartite Agreement of 2024. System-wide interventions can include local government, business, civil society organisation, local leaders, influencers and communities.

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PUBLIC OPINION & ENGAGEMENT

Growing public support for decarbonisation efforts are important for multiple reasons. First, politicians and business leaders are, in many contexts, accountable to and dependent on the public (e.g. through voting, consumer decisions). Public support for pro-climate actions can thus encourage leaders to implement bold climate and nature-related policies, and businesses to make longer term investment decisions or to structure their businesses to reduce their footprints.

Second, structural changes to our infrastructures, economies and livelihoods, and institutions require public support and buy-in to be effective. Third, the public will also have to change how they work, travel, eat, heat/cool their homes and so on — and since people look to each other when deciding how to act or what to care about, these changes can spread, creating new social norms and shared values. How we turn growing public concern about climate change into action is context and group specific and is an area of active research. In more polarised contexts, it may involve avoiding mention of climate change altogether and focusing on immediate and local economic and health co-benefits.

PUBLIC SUPPORT FOR PRO-CLIMATE AND PRO-NATURE ACTIONS

Public support provides an essential mandate for effective policy actions, but is vulnerable to politicisation and polarisation.

Progress:

The public perception that we are in a climate crisis is growing. The share of people globally who consider climate change a major threat increased from 54% in 2016 to 62% in 2017, to 71% in 2022 (Pew Research Center, 2022). In a 2023 survey, 93% of respondents stated that "climate change poses a serious and imminent threat to the planet" (Edelman Trust Barometer, 2023). Half of these respondents said that their views had changed over time. In 2024, the Peoples' Climate Vote found that 80% of people want their country to do more on climate change and 72% want their country to move away from fossil fuels quickly (UNDP, 2025). The increasing appetite for national action on climate change was echoed in a 2022 survey of 40,000 people across 20 countries that are collectively responsible for 72% of global CO_2 emissions, where 80% of people agreed that "their country should fight climate change" (OECD, 2022). The sense of urgency for personal action also appears to be growing: in a 2023 global survey, 80% of people agreed that "we are heading towards an environmental disaster unless we change our habits quickly" (IPSOS, 2023).

- Across many countries, women are more likely than men to consider climate change a major threat, especially in wealthier countries (Bush and Clayton, 2023). Education is also correlated with greater concern (Pew Research Center, 2022).
- In the UK, the biggest change was observed among those over 65 years old: in 2013, only 36% said that humanity was causing climate change. By 2021 that figure had more than doubled to 74% (YouGov, 2021).
- In the US, only 22% of those on the political right say global climate change is a major threat to their country, compared with 85% of those on the political left - a Left-Right difference of 63% (Pew Research Center, 2025).
- However, most other countries are much less polarised. For example in South Korea, 79% of those on the political right say global climate change is a major threat to their country, compared with 87% of those on the political left - a Left-Right difference of only 8% (Pew Research Center, 2025).

BALANCING OR RESISTING CHANGE

- **Disinformation campaigns** from right-wing political parties and media, funded by the fossil fuel industry and think tanks, sow doubt about the science, exaggerate the cost of climate policies, or call for delay.
- **Entrenched norms, habits, customs and social identities** that rely on carbon-intensive practices.
- **Affective political polarisation** where pro-climate actions or sustainability norms become associated with certain political groups, leading other groups to reject those actions or beliefs.

REINFORCING OR ENABLING CHANGE

- **Emergence of new social norms** aligned with sustainability and low carbon practices (e.g. repair cafes, libraries of things, active travel)
- **Positive political feedback** (e.g. declarations of climate emergency).
- **Positive policy feedback**: falling costs, positive experiences, and increasing adoption of clean technologies builds support for more ambitious policy.
- **Growth in green economy** jobs or local health benefits of reduced pollution.
- Establishing a **clear collective vision of a desirable post-carbon future.**
- **Replace GDP growth with 'good growth'** - economic growth needed for human development and wellbeing within safe planetary boundaries and just social foundations - as the primary measure of economic progress.

ENABLING POLICIES:

- Well designed, impartial climate assemblies, information campaigns, and education that enable people to understand the real risks and opportunities, discuss the difficult decisions and trade-offs, and make incremental or rapid change a conscious choice.
- The recommendations of climate assemblies to be given legal status in government policymaking such that the public co-create the transition.
- Accessible and affordable low-carbon alternatives.
- Correcting misperceptions by communicating public concern and support for pro-climate policies to the public and elected officials.

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3.4 Renewable power and electrification: from tipping in technology adoption to system transformation

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Key Messages:

Electrification presents key positive tipping point opportunities

- **Electrification is a decarbonisation multiplier: electrifying heating, transport, and industry both reduces emissions and stimulates investment in new renewables. It increases the overall efficiency and flexibility of the energy system.**
- **Integration can accelerate the self-propelling growth of renewable electricity generation, but requires urgent grid upgrades, energy storage, and demand flexibility.**
- **New digital technologies that can optimise energy balancing and storage between commercial and domestic energy providers need to be accelerated.**

Targeted policies can accelerate electrification

- **Decoupling renewable electricity pricing from fossil fuel-linked marginal pricing could significantly benefit consumers and accelerate change.**
- **Co-adoption strategies can trigger positive tipping: bundling complementary technologies increases value, reduces risk, and speeds clean technology diffusion.**
- **Policy should target households during key renovation and purchasing moments.**

Electricity generation by renewables has shown continued growth since the GTPR2023. Wind and solar are now the fastest-growing energy generation technologies in history. The world has passed the 30 per cent renewable electricity milestone, and in the EU, almost 50 per cent of electricity was generated by renewables in 2024, a record (IEA 2024, Wiatros-Motyka et al., 2024, IRENA 2024), See Section 3.3 and Figure 3.4.1 below for an overview.

Countries outside of the EU where the growth of clean power exceeded electricity demand growth include Australia, Korea, the United Kingdom, the US, Argentina, Japan, South Africa, Brazil, and Mexico (IEA 2024). For the first time, China's emissions were down 1.6 per cent year-on-year in the first quarter of 2025 due to its growth in clean power generation (Carbon Brief, 2025). In these countries, renewable energy developments are increasingly market-driven rather than subsidy-driven; investment in renewable energy technologies is attractive even without support from subsidies. This sometimes leads to tensions. Specifically, in developing countries where electricity demand still needs to grow to meet essential needs, we observed that fast growth in distributed renewables sometimes threatens the business case for electricity grids. While these tensions between distributed and centralised solutions are common to energy transitions around the world, they play out differently in different countries and bring different energy justice concerns.

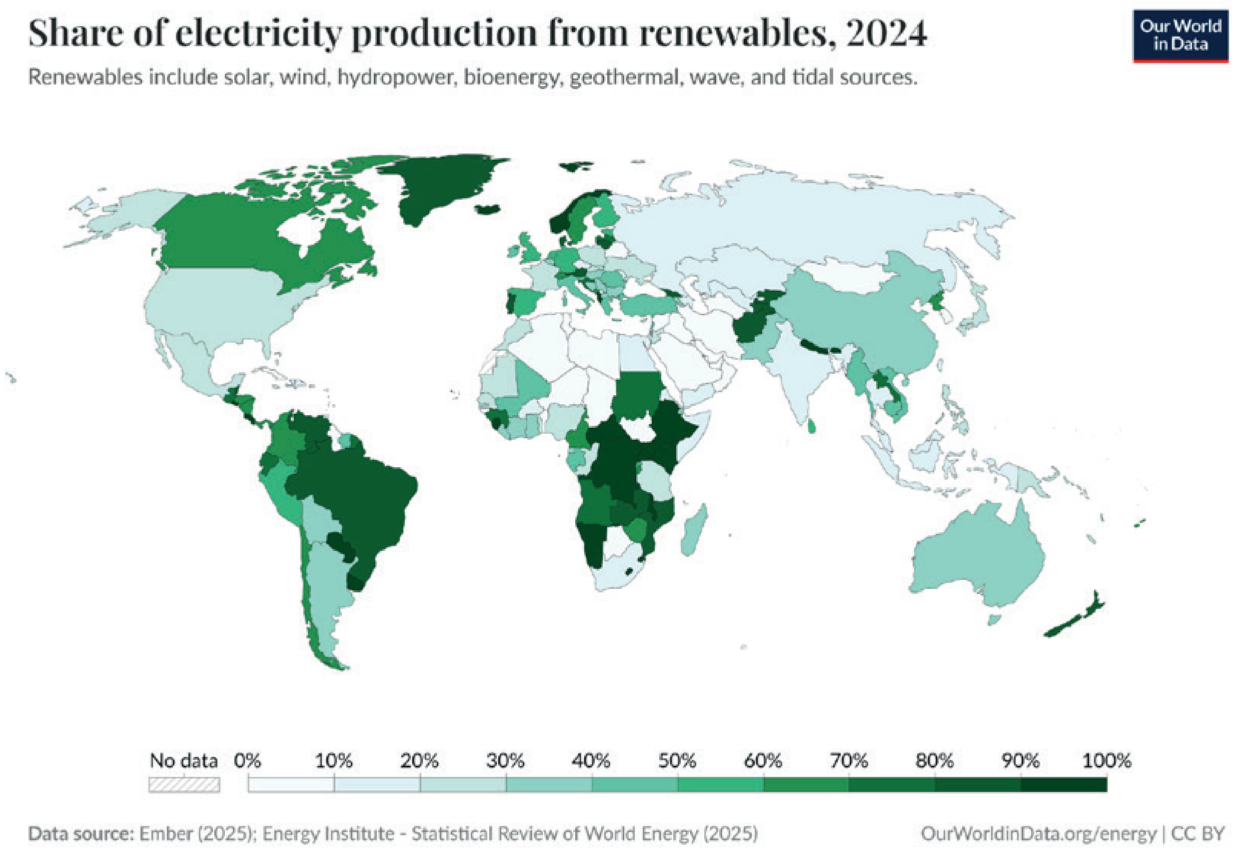

Figure 3.4.1: Share of electricity production from renewables 2024 (Our World in Data).

Now that the progress in these technologies is increasingly self-propelling due to technology-induced tipping (see Section 3.3), the challenge for the energy transition moves from bringing down the cost of individual technologies to ensuring system integration. Specifically, the growth in clean generation capacity needs to be complemented by an acceleration in the electrification of demand to bring down carbon emissions from fossil fuels. Increasing demand flexibility will be helpful here. When users are able to shift their electricity demand in time and space, for example, by smart steering strategies for EVs or heat pumps, it will be easier to match renewable energy supply with demand, and the need for investment in additional renewables and storage capacity will be lower (see Section 3.3). Barriers to this system transformation include power system integration, finance and investment, lack of human capital, but are also found in the deployment of smart meters and the implementation of demand flexibility at the household level (IRENA, 2024).

Despite these barriers, there are several possibilities for positive feedbacks that can induce further tipping on the demand side. Specifically, demand electrification often comes with increased energy efficiency, further supporting emission reductions (Breyer et al., 2022; Rissman et al., 2020, IEA 2024). Electrification is also key to maintaining a strong business case for building new wind and solar generation and creating incentives to invest in additional capacity. Moreover, for a range of applications, electrification also opens up opportunities to increase demand flexibility, further supporting the integration of variable renewable energy generation capacity. Electric vehicles and stationary batteries that provide grid services are key examples here. Dutch grid operator Stedin, for example, estimates based on ongoing experiments that 500 shared electric vehicles can provide 10 per cent of the required grid flexibility in Utrecht, a city with 370000 inhabitants and currently around 900 shared vehicles.

This development is greatly stimulated by the game-changing price reductions observed for batteries. In December 2024, energy research provider BloombergNEF reported that Lithium-ion battery pack prices dropped 20 per cent from 2023 to a record low of US$115/kWh (see Section 3.3). They also signalled an expected overcapacity from Chinese suppliers. Together, these developments support a positive feedback loop between increased electricity generation by renewables and demand electrification.

However, the demand electrification of key demand sectors housing, transport and industry proceeds at different speeds. In housing, the high upfront investment costs for heat pumps and the required renovations (insulation, changes in pipework) act as barriers to adoption. In industry, demand electrification is slow, partly due to the lack of cost reductions in necessary technologies - such as for green steel, green chemicals and green cement (Ember, 2025) and partly due to technological and policy uncertainty. For example, investment decisions on electrolysers are delayed by uncertainty about markets, business models and regulation despite technological learning (Galetti et al., 2025). The electrification of transport is economically attractive but depends on the build-out of charging infrastructure and policy support (IEA Global EV Outlook 2024, Hoekstra and Alkemade, 2025). Differences in support lead to very different growth rates for electric vehicles in different countries. While both are very rich countries, Norway is an example of a high support, high growth country, while Switzerland has a limited number of EVs, charging stations and purchase subsidies in place.

3.4.1 Opportunities for positive tipping in household demand

Households are responsible for a large part of emissions caused by electricity use, heating, transportation and indirectly by consumption (Ivanova et al., 2020; Pang et al., 2019). Changes in the choices of households, therefore, also affect the other sectors. The level of household energy demand differs between countries, and within countries between income groups, but electricity, heating, and land transportation are significant emission sources across the board (IPCC 2023). The large differences between countries indicate that there is room to move towards more sustainable lifestyles, either enabled by better technologies or by reducing demand (Akenji et al., 2021). Examples of such changes are increased building insulation or behaviour change. Below, we zoom in a bit more.

For the EU's household demand electrification, we observe fast changes in some countries. The electrification of heating (responsible for around 60 per cent of final energy consumption in the EU residential sector) benefits from the fast decarbonisation of the electricity supply. However, demand for heating still tends to be met by natural gas boilers. In 2022, natural gas accounted for 42 per cent of global heating energy demand, with a 30 per cent share of the heating mix in the European Union (Eurostat) and over 60 per cent in the United States (EIA n.d.). When low-carbon, sustainable heat sources are available, this may be a preferred option. However, when this is not the case, electrification of heating demand through heat pumps can lead to a considerable reduction in energy demand. Section 3.3 illustrates how the fast growth in heat pump adoption can reduce the emissions from heating considerably (IEA, 2022). Nevertheless, the shift to low-carbon heat sources requires changes in technologies and infrastructure in houses and neighbourhoods. In the EU, heat pumps are expected to play a significant role in the building sector. Heat pumps can supply cooling as well as heat for space heating and tap water. The demand for cooling is increasing, and meeting that demand with traditional air conditioners is already leading to significant increases in energy use.

As of 2023, there were more than 21.5 million heat pumps installed in the EU (European Commission 2024). The share of heat pumps for domestic heating varies from around 90 per cent in Sweden and Finland to around 10 per cent in Hungary. Between 2013 and 2022, heat pump sales experienced continuous growth, reaching a peak in 2022 when they increased by 44 per cent compared to the previous year. However, 2023 saw a slowdown, with a drop of 7 per cent compared to the record year. Despite this fast growth, heat pumps only represent a small share of new installations in Europe (6 per cent in 2021 - European Heating Industry), and gas boilers remain the dominant technology. In countries with fast growth, we observe several drivers and feedback loops. Sufficient insulation is a key condition for the economic attractiveness of heat pump adoption. Here, we see an advantage of stricter housing regulations (often in countries with colder climates). But sometimes other non-technology factors play a role. For example, in the Netherlands, the adoption was driven by the decision to phase out natural gas and concerns about the affordability and availability of natural gas following the war in Ukraine.

3.4.2 Barriers & intervention points

Tipping through demand electrification depends on the supply of electricity from renewables. The levelised costs of energy from renewables outcompete (in new-for-new comparison) or are competitive compared to fossil fuel-generated energy (Nijsse et al., 2023). As wind and solar energy are available at no cost, but fossil generation does not have this advantage, the outlook with continued technological learning is favourable. However, there are some barriers that slow down market-driven progress:

First, in many countries, renewable energy prices are linked to fossil fuel prices. Specifically, under marginal pricing, natural gas is often price-setting. In the EU, for example, natural gas was the price-setter 63 per cent of the time in 2022, with only a 20 per cent share in the electricity mix (JRC, 2023). This prevents consumers from fully benefiting from the energy transition, reducing the attractiveness of investing. Here, decoupling is necessary to ensure that benefits are passed on to consumers (Draghi, 2024). Power purchase agreements (PPAs) and contracts for difference may help here. The use of PPAs is more advanced in the US compared to Europe. Moreover, as discussed above, the fast-decreasing costs of battery storage may be a game-changer in the power sector, reducing the need for gas-fired power plants during peak times.

Second, while renewables' operational costs are typically low compared to fossil fuel-based technologies, capital expenditures are often higher. This is true for heat pumps, electric vehicles, and grid-scale wind and solar. Finance instruments that are connected to the building rather than to the owner are explored in pilot projects as a potential solution.

Specific barriers to electrifying household heating demand are the lack of technologies for heat longer term heat storage and the cumbersome installation process of heat pumps, and the high upfront investment costs, as well as concerns about running costs (see section 3.3).

Accordingly, interventions need to be part of a systemic policy mix (Alkemade et al., 2024; Kern et al., 2019). As an example, leverage points in the transition to heat pumps in Sweden included a carbon tax on heating oil and the availability of cheap electricity. Another leverage point is minimum energy performance standards for buildings (EU, Canada). Building renovations often happen when a building changes hands; this provides a natural opportunity to attach levers. Energy performance requirements play an important role in ensuring that renewable supply can keep pace with the growth in energy demand. This especially holds for buildings and technologies where energy-efficient alternatives are available at comparable prices (like air conditioning). A key driver that receives limited attention is the health co-benefits that come with better-insulated homes and the phase-out of gas-fired stoves (Breysse et al., 2011; Jarvis et al., 1996).

For countries that observe a fast growth in renewables supply, this means support for the electrification of demand and the build-out of the supporting infrastructure, including electricity grids and charging infrastructure. A move toward energy autonomy at the household scale supports this transition at the national level as it reduces the demand for grid capacity. A key energy justice concern is to divide the costs of grid expansion in a fair way.

3.4.3 Co-adoption of technology as a driver of positive tipping

To go from social tipping in the adoption of specific technologies like heat pumps, electric vehicles or rooftop solar PV to a full system transition towards sustainable and affordable energy for all (Sustainable Development Goal 7), requires a systems approach (Campfens et al., 2025). Connecting tipping in one energy behaviour to tipping in other behaviours or at larger scales leads to increased resilience of the new system, reducing the reversibility of the tipping behaviour. Here, the concept of co-adoption is increasingly studied.

The co-adoption of technologies unlocks the full potential to reduce household emissions, enhance energy efficiency and contribute to a more resilient energy system. This is for example, when renewable energy from photovoltaics provides electricity for both the heat pump and the EV (Priessner and Hampl, 2020; Stauch, 2021; Agnew and Dargusch, 2017; Quoilin et al., 2016; Truong et al., 2016), while an energy management system optimises energy flows, increasing the level of energy self-consumption and balancing the energy grid (Liang et al., 2022; Shen et al., 2023). Marketing research suggests that consumers positively evaluate bundles of complementary products as they offer greater value through complementarity, reduce perceived risk, and enhance convenience by saving time and effort spent on a purchase (Stremersch and Tellis 2002).

Leveraging integrated technology solutions is essential whenever households inquire about stand-alone technologies like photovoltaics or renovate their building. These not only accelerate technology adoption but potentially support the advancement of less mature technologies, such as EVs and reduce the risk that people will revert to the older unsustainable technologies (Reinders et al., 2010; Plananska and Gamma, 2022).

Examples are when people co-adopt electric vehicles, heat pumps, home insulation and solar PV because the synergies between the technologies enable households to benefit more from the energy transition and or adopt a sustainable or energy-independent lifestyle. Several countries have schemes that stimulate co-adoption, from purchase price subsidies (Germany, The Netherlands) to tariff incentives (Australia). Social tipping is more likely to scale up when there is a diversity of drivers, appealing to different groups of adopters. For households, we observe such diversity (Martinez-Alcaraz, et al., 2025). Energy affordability is a key and universal driver, but concerns about climate, concerns about energy security and the desire to be energy independent (both on the national and on the local scale – independent from large energy suppliers) also play a role in household energy decisions. Cost reductions and performance improvements through learning remain a main driver of the energy transition, as this creates affordability for a larger group of people.

Policy actions:	• Focus on systemic approaches, leveraging co-benefits and the momentum generated by quick cost reductions. • Reduce uncertainty for firms and consumers that consider switching by providing stable, long-term support.
Business and finance actions:	• Focus on modularisation and standardisation • Design innovative finance models that help reduce risk for adopters
Wider publics and civil society actions:	• Share success stories and positive experiences. Emphasise co-benefits

3.5 Positive tipping points in food systems, land use and nature

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Key Messages

Positive tipping points in agricultural commodity supply chains can end deforestation and conversion

- Triggering positive tipping points in the sustainable production and consumption of agricultural commodities requires mutually reinforcing actions in three areas: Clear policy signals and enforcement; coordination across supply chains and between key markets; and finance to support transitions in production.
- Legal protections for tropical forests and their inhabitants need to be established and enforced.
- Standards for sustainable commodity production (e.g. soy, beef, cocoa, cotton, palm oil) and trade need to be developed and enforced. Successful moratoria (e.g. Amazon Soy) show that regulation and monitoring are essential for compliance, and that alternative options for producers must be available (and financially viable).
- Demand-side interventions in import markets must align with domestic policy in major producing countries to ensure success, and should make efforts to support producers in meeting new standards through provision of transition finance.
- Policy and market structures currently incentivise harmful practices. Subsidies and procurement should change towards sustainable production and consumption, thereby supporting sustainably productive landscapes that include standing forests.

Positive tipping points can rapidly restore nature and biodiversity

- Ecosystem restoration can positively tip degraded systems back to health, through interventions like keystone species reintroduction, nutrient reduction, and clumped planting that activate natural reinforcing feedbacks.
- Recovery of food and water resources can be positively tipped through promoting community governance of common pool resources including groundwater, forests, fish stocks and the creation of marine protected areas.
- Positive tipping points in the spread of nature-positive farming, conservation and regeneration initiatives... / Scaling nature-positive initiatives depends on local benefits and governance. Community management, equitable benefit-sharing, and leveraging ecological feedbacks enable rapid spread. Combining local agency with supportive policy increases durability.

Introduction

Agriculture and associated land use contribute a quarter of global greenhouse gas emissions, of which half result from forest loss and degradation (Crippa et al., 2021). When energy use and other supply chain emissions are included, the food system as a whole contributes a third of GHG emissions globally. In terrestrial, freshwater and marine ecosystems food production is a key driver of nature loss and ecosystem degradation, especially in critical ecosystems like the Amazon and coral reefs where its impacts, compounded by climate change, increase the risk of tipping points leading to their irreversible loss (see Section 2). Deforestation is also a major human health risk, increasing the risk of zoonotic disease spread (Chin et al., 2020; Morand and Lajaunie, 2021) and exposing hundreds of millions of people to increased heat stress in the tropics (Reddington et al., 2025).

Meeting the goals of both the Paris agreement and the Kunming-Montreal Global Biodiversity Framework (GBF) (Leclère et al., 2020) requires urgent acceleration of shifts to sustainable and equitable production, trade and consumption across food supply chains globally. As the GBF makes clear, such changes will also require major shifts away from financial investments in unsustainable production towards financing the transition to sustainability.

Positive tipping point opportunities to transform food production and consumption can operate synergistically to increase food security, restore ecological health to agro-ecosystems, reduce pressure on natural ecosystems and ultimately create opportunities for nature restoration by reducing the overall land footprint required for food production. Nature regeneration, and initiatives that promote it, can in turn be positively tipped. The opportunity is to move the food system from problem to solution.

In this chapter, we summarise current knowledge of actions and amplifying feedbacks that could reduce the most significant drivers of deforestation and degradation. We identify potential interventions that policy makers, civil society actors and retailers can take to accelerate a just transition. We then assess the potential for positive tipping points to accelerate nature recovery and restoration of ecosystems services in both managed and natural landscapes by working with reinforcing feedbacks that occur in nature and societies.

3.5.1 Ending deforestation in agricultural commodity supply chains

Half of all habitable land is currently used for agriculture and, of this, 80 per cent is used to raise livestock, including the land used to produce animal feed (Ritchie and Roser, 2019). Whilst most agricultural production is not currently directly driving deforestation, most deforestation is driven by agricultural expansion (Rajão et al., 2020; Pendrill et al., 2022). A demand side tipping point based on lowering global demand for livestock products would help protect forests (Box 3.5.1) but is not alone sufficient, or sufficiently rapid, to protect critical biomes from existential threats arising from deforestation and degradation; especially in the Amazon rainforest (see 4.1 Amazon Case Study). In tropical forest biomes which produce cash crops like soybean, palm oil, coffee and cocoa, urgent action is required to tackle commodity driven deforestation. This includes the need to establish and enforce legal protections for tropical forests and their inhabitants, develop and ensure standards for sustainable commodity production and trade, finance the transition to sustainable production, and support sustainably productive landscapes that include standing forests.

Box 3.5.1: Shifting to sustainable diets

GTPR 2023 highlighted the powerful synergy between efforts to shift to sustainable production and supply chains, and demand-side shifts that reduce the overall impacts and spatial footprint of food production including reducing food loss and waste and reducing consumption of livestock products in overconsuming countries. Of these, the latter holds the strongest potential for tipping dynamics due to its strong association with peer influence and social norms which can spread via contagion.

While globally meat consumption has continued to rise due to population growth and rising incomes, in some over-consuming regions there are signals that consumption of animal products has peaked and is decoupling from economic growth (e.g. in USA, UK, Canada, Australia, Saudi Arabia, New Zealand, Switzerland, Israel; (Whitton et al., 2021). At the same time, purchases of plant-based meals have increased in some markets, especially in Europe (where Germany and UK are the largest markets), and a near doubling of investment over the last decade in plant-based 'alternative proteins' demonstrates a growing sector with increasing market power, albeit one in which momentum has slowed in recent years.

These trends have in part been driven by overlapping concerns for consumers around health, environmental impacts and ethics of overconsumption of animal products (Rosenfeld, Rothgerber and Tomiyama, 2020; Dagevos, 2021). Other significant interventions include resetting of national dietary guidelines in some countries (e.g. Denmark, Germany, Norway) to reduce recommended consumption of animal products. However, the political economy of shifting consumption patterns remains complex and contentious due to significant public investment in livestock farming, transition risks for farmers and wider rural economies, and strong cultural value associated with food and farming landscapes.

Further information on enabling factors and barriers for shifting diets is given in Chapter 3.3.

Effective action can generate systemic change. Different actors, from consumers to policy makers, traders, producers, investors and civil society organisations, can play important roles in developing, demonstrating and propagating models for nature positive value chains. When successfully established, these have potential to tip the wider system behaviour through **network effects** (see Section 3.2.3 and Appendix 1: Glossary), where actors participating in nature positive value chains benefit more than those not participating; through **contagion**, for example by national and regional level bodies adopting standards to align with international agreements or transnational standards, and through **introducing path dependencies** in legislation, infrastructure and information flows (Fesenfeld et al., 2022; Sewerin, Fesenfeld and Schmidt, 2023).

Current supply chain commitments have mixed success. To date, a number of zero-deforestation commitments (ZDCs) have been implemented with mixed results, from international pledges like the Glasgow Leaders' Declaration on Forests and Land Use (The National Archives, 2021), to commitments at national level or relating to specific commodities and supply chains (Box 3.5.2), but these have so far failed to reverse deforestation (Lambin and Furumo, 2023).

Box 3.5.2: Enabling conditions for success of the Brazilian Amazon Soy Moratorium

The Amazon Soy Moratorium (ASM), considered one of the more successful ZDCs, was signed in 2006 following an NGO campaign linking major traders responsible for 90 per cent of the trade in Amazon-produced soy with deforestation. Under the ASM, traders agreed not to purchase soy from newly deforested areas in the Brazilian Amazon Biome. Deforestation in key soy producing areas fell as a result and between 2006 and 2014 only 1 per cent of new forest clearing in the Brazilian Amazon biome was associated with soy expansion (Lambin and Furumo, 2023). Instead, soy cultivation intensified while expansion in the Amazon biome was concentrated in forest areas cleared before implementation of the ASM.

The success of the ASM can be attributed to a number of enabling conditions (Lambin and Furumo, 2023):

1. **Alignment with existing regulation:** The ASM provided a market mechanism to reinforce the already existing Brazilian Forest Code, while adding few additional requirements for producers.
2. **Alternatives available to producers**: Availability of land already cleared before the ASM was imposed, opportunities to intensify through e.g. double cropping, and opportunities for expansion in other areas (e.g. the Cerrado) meant that opportunity costs to producers were low.
3. **Concentrated supply chains, and large export market with demand for zero deforestation products:** A 'naming-and-shaming' campaign by NGOs in key export markets had power to influence traders, who in turn were able to exert powerful direct influence on producers.
4. **Reinforced by government action:** The introduction of the ASM was accompanied by Brazilian government policies that expanded protected areas, increased enforcement efforts, supported satellite based monitoring and created a Rural Environmental Registry.

Despite the success of the ASM in reducing soy-related deforestation in the Amazon biome the simultaneous expansion of soy production in the Cerrado, which is also a globally significant biodiversity hotspot, demonstrates the importance of integrated regional policy and supply chain solutions, based on systems understanding to account for risks of displacement and leakage. In this case, a parallel Cerrado soy moratorium was strongly opposed by producers' associations.

The importance of continued government support for monitoring and enforcement is also clear. Reduction of resources for enforcement of land use regulations has been associated with an increase in non-ASM compliant soybean cultivation from 0.07 per cent in 2008 to more than 6 per cent in 2019 (Lambin and Furumo, 2023).

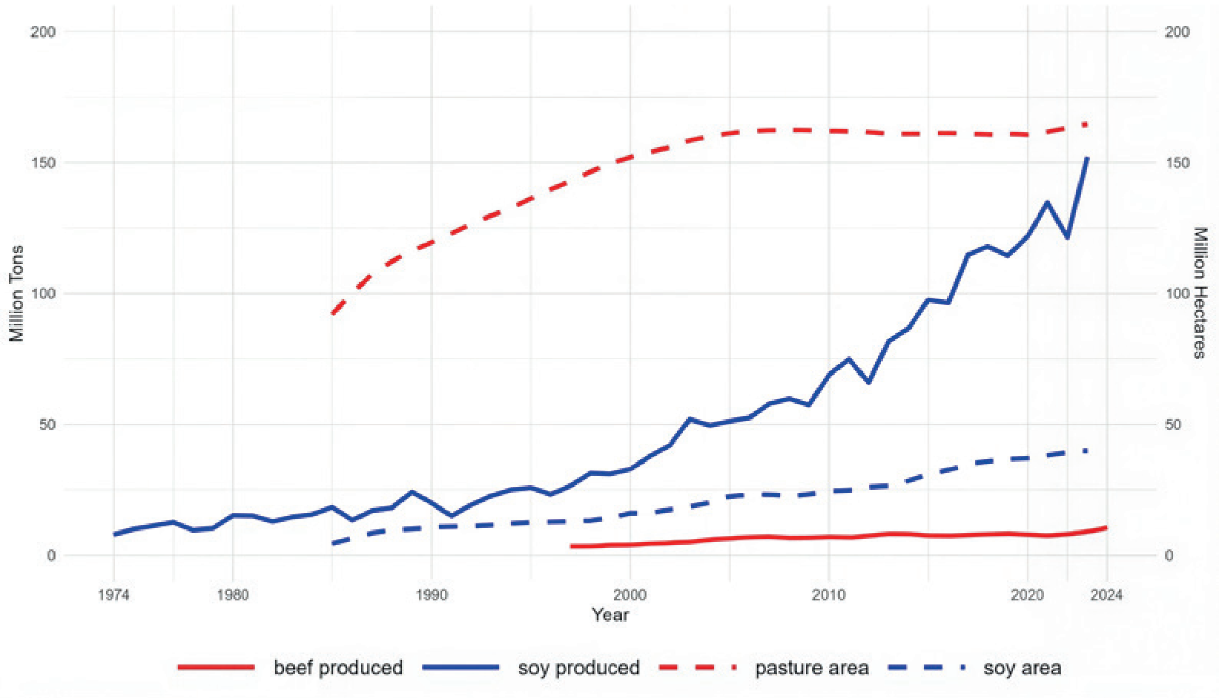

Figure 3.5.1: Soy and Beef production through time, compared with soy and pasture area through time, across Brazil, based on estimates of production from IBGE and Mapbiomas 9.0 land use (Global Land Use and Environment Lab (GLUE) at the University of Wisconsin - Madison (UW) & Land Conservation Association (LCA), 2025).

The relative success of the Amazon Soybean Moratorium (ASM, Box 3.5.2) demonstrates that policy and market-based interventions can reduce deforestation under the right conditions. Other comparable initiatives have been less successful where these conditions have not been met. For example:

- The **Brazilian cattle agreement** (CA), in which slaughterhouses and meatpacking companies signed an agreement to stop purchasing cattle from properties with illegal deforestation to convert forest into cattle pasture, was modelled on the ASM but has been less successful. The more complex nature of cattle supply chains with more actors and individual animals likely to move several times between farms before they are slaughtered makes compliance and monitoring less reliable (Lambin and Furumo, 2023).
- Under the **Indonesian forest moratorium**, the Indonesian government suspended granting of new concession licenses for logging, timber plantations and palm oil within certain areas such as dryland forests and peatland forests from 2011-2021. However, low compliance and weak enforcement in key areas including peatlands has undermined its moderate successes (Groom, Palmer and Sileci, 2022).

Demand side initiatives are emerging. Importing countries have started to propose and adopt regulations against commodity-driven deforestation. In the EU, regulation on deforestation-free products (EUDR) entered into force in June 2023. Traders must prove that commodities that enter or leave the EU do not originate from recently deforested land and have not contributed to forest degradation (Cesar de Oliveira et al., 2024). Similarly, the UK has committed to legislation which prohibits the use of illegally produced forest risk commodities (Participation, 2021). However, concerns have been raised that mis-alignment with domestic policy in Brazil and other Amazon countries may lead to increased barriers to producers and traders, and at worst provide loopholes that weaken the ASM and incentivise expansion of soybean production into recently deforested areas (Oliveira et al., 2024). When implemented effectively, demand side trade measures can help provide long term preferential market access.

Coordination is required across major markets, including domestic markets in exporting countries for such demand-side initiatives to be successful. For example, while they constitute a significant export market the EU and UK markets combined are significantly smaller than both the Chinese market, and the domestic markets of Amazonian soy producing countries (Lambin and Furumo, 2023). Since non-ASM compliant soy makes up only a small percentage of total cultivation (<10 per cent), if key export markets are not aligned on standards it is likely that this soy will simply be redirected to less discriminating markets, with little effect on overall production.

Financing transition costs for producers is essential. Regulating trade alone is insufficient as producers may face costs to the transition, such as investments in restoring abandoned or degraded land for production. It will be essential to make it accessible and profitable for producers of all scales to transition to sustainable production, and it is not reasonable to expect the burden of these costs to be met by producers alone. Countries applying higher standards through trade measures must back these with finance to meet the costs of transition.

Transition costs are not evenly distributed. Smallholder farmers, for example, are unlikely to have technical capability and financial resources to comply with externally imposed regulations like those introduced by the EU and UK (Cesar de Oliveira et al., 2024). This needs to be addressed through domestic public policies as well as EU, UK and other international investments and implementation of cooperation mechanisms that lower the administrative and financial burden of small-scale farmers.

Effecting qualitative, systemic shifts to sustainable supply chains requires coordination between government policy in producing and exporting countries and major consumption markets, private sector actors across the supply chain, public and private finance, NGOs and civil society.

1. Foremost, local laws protecting forests, and the rights of indigenous peoples, need to be established (where absent), rolled out, or enforced, depending on the context – which requires political will and enforcement capacity.
2. Existing farmland needs to be optimised and finance made available to meet the costs of transition, for example in accessing and rehabilitating abandoned and degraded land and in increasing productivity.
3. Market signals need to reinforce action to prevent deforestation, by providing incentives and disincentives. These should take the form of exclusive market access for legal produce and preferential market access for sustainable products (avoiding unfair cheaper competition and rewarding responsible producers and that provide a long term assurance of market access).
4. NGOs and civil society organisations can promote demand for deforestation-free products, hold producers and policy makers accountable, and protect the interests of vulnerable actors like smallholder farmers.

These should not be regarded as a menu of options, but rather a list of mutually reinforcing actions that, if taken together, can trigger positive tipping. **Success lies in multiple complimentary interventions:**

Policy actions:

In countries which are producers and exporters of tropical forest risk commodities:

- Enforce legal protections such as preventing illegal deforestation in protected areas, setting uncontrolled fires and incursions/occupation into indigenous lands.
- End public finance/subsidies for unsustainable production
- Facilitate and incentivise development and adherence to sustainable production standards
- Facilitate compliance with laws protecting forests through effective monitoring and enforcement
- Implement policies to avoid marginalization of vulnerable actors such as extension services to help farmers meet sustainability standards
- Provide legal and regulatory frameworks that support the growth of high-integrity ecosystem service markets (e.g. green bonds)
- Support growth of sustainable bioeconomies

In countries which are importers of tropical forest commodities:

- Work with exporting countries to develop and enforce supply chain standards and regulations that discourage or prohibit imports of deforestation-linked commodities while supporting sustainable practices and economies in exporting countries and regions.
- Form coalitions/blocs across major markets with consistent standards and requirements.
- Provide financial means, technical assistance and capacity building for smallholders to access international markets
- Increase demand for deforestation-free commodities through public procurement policies, labelling requirements, investors standards and information campaigns

Business and finance actions:

- Provide private and public finance to meet the costs of transition to sustainable production
- Develop and lobby for strong standards and regulation that level the playing field for progressive companies
- Ensure supply chain accountability and transparency
- Commit to disclosure and natural capital accounting
- Traders and producers: make zero-deforestation commitments including measures to enable monitoring and traceability
- Retailers: commit to reducing the environmental footprint of products sold (e.g. major UK retailers committed at COP26 to halving environmental impacts by 2030 (BBC, 2021)).

Wider publics and civil society actions:

- Advocacy and campaigning, communicating and building awareness to grow demand for deforestation-free products
- Independent monitoring, accountability and standard setting
- Legal action
- Collaborate with business and other partners to enable consumers to make informed choices, e.g. through traceability of product ingredients
- Protect the interests of vulnerable groups including smallholder farmers, indigenous peoples and other forest dwellers.

3.5.2 Positive tipping points for restoring nature and biodiversity

196 countries have signed up to the Kunming-Montreal Global Biodiversity Framework (Convention on Biological Diversity, 2022) that aims to halt and reverse biodiversity loss by 2030. The GBF includes a target to restore 30 per cent of all degraded ecosystems and conserve 30 per cent of land, waters and seas, by 2030.

Yet more than halfway through this UN Decade on Ecosystem Restoration, progress is far slower than it needs to be to meet these targets. Positive tipping points can play a key role in accelerating the restoration of nature, where pressures on land and sea use have been reduced (by initiatives like those described above). Here we highlight key actions to positively tip ecosystem restoration, resource recovery, and the spread of nature positive initiatives, and the potential for them to be combined to positively tip larger scale ecological recovery.

Figure 3.5.2. Location of examples of positive tipping points for nature discussed herein.

Positively tipping ecosystem restoration

Ecosystems that have been negatively tipped can be positively tipped back from a degraded state, by reversing anthropogenic drivers. It often takes a larger change in drivers to tip recovery than it did to trigger collapse, but numerous successes have been achieved (Figure 3.5.2). The secret is to work with the reinforcing feedback mechanisms that are already present in nature.

Reintroduce keystone species. Reintroducing a keystone species that was previously eliminated can positively tip ecosystem recovery. For example, reintroducing wolves to Yellowstone National Park in 1995-6 suppressed elk and deer populations triggering abrupt vegetation recovery and boosting populations of scavengers, songbirds, bison, and beaver (Ripple et al., 2025). The recovery and reintroduction of sea otter populations off the North Pacific coast of the US and Canada suppressed sea urchin populations and allowed kelp forests to abruptly recover (Selkoe et al., 2015). These cases increased carbon storage (in trees and kelp), biodiversity, recreation and tourism. There is huge potential for wider reintroduction of apex predators to positively tip vegetation recovery (Perino et al., 2019; Xu et al., 2023).

Reduce nutrient loading. Reducing nutrient loading of aquatic ecosystems can positively tip their recovery. Efforts starting in the Norfolk Broads and the Netherlands have shown that reducing phosphorus loading can reverse eutrophication of shallow lakes and positively tip them into a clear water state (Scheffer et al., 1993). This can be helped by introducing filter-feeding ecosystem engineers such as zebra mussels and piscivorous fish that suppress planktivorous and benthic fish allowing zooplankton and benthic filter feeders to recover (Jeppesen et al., 2007).

Clump reintroduction. Clumped reintroduction of salt marsh plants, mangroves, seagrasses, mussels and oysters can positively tip recovery of tidal ecosystems. This works by activating reinforcing feedback whereby these ecosystem engineers stabilise sediments and attenuate waves and currents, facilitating their persistence (Silliman et al., 2015). Positive tipping can be aided by introducing engineered structures like fencing for mussel beds or permeable dams for mangroves (Temmink et al., 2023). Excluding bioturbating animals that destabilise sediments (Suykerbuyk et al., 2012), or encouraging shorebirds that eat them can further help (C. Li et al., 2023). Clumped reintroduction can positively tip other stressed ecosystems including arid vegetation and peat bogs (Temmink et al., 2023).

Multiple actions for coral reefs. Reducing multiple local drivers can positively tip the recovery of tropical coral reefs, at least buying time from the increasing threats of global warming (see 4.3 Warm-water Coral Reefs Case Study) (Graham et al., 2013). Recovery depends on herbivorous fish being abundant enough and nutrient levels low enough to suppress macroalgae (Graham et al., 2015). Hence positive tipping can be enabled by controlling fishing and reducing anthropogenic nutrient loading (Holbrook et al., 2016). It is also aided by deliberately introducing juvenile corals, or artificial reef structures, supporting seabirds (Benkwitt et al., 2023), and taking advantage of natural variability that impairs macroalgal production, such as persistent cloudy conditions (Graham et al., 2013).

Box 3.5.3: Tipping recovery in the Baltic Sea

The Baltic Sea and its catchments have experienced multiple negative ecological tipping points (Reusch et al., 2018), but it has the potential for large-scale positive tipping of recovery. This shallow, brackish coastal shelf sea is effectively a giant estuarine system. Historically it has seen a trophic cascade tipping point in the 1950s-60s with the removal of seals as top predators. Then the 1980s saw a pelagic tipping point from overfishing, deterioration of spawning grounds, and climate change, with an abrupt switch from cod to sprat and herring. Numerous coastal tipping points have occurred involving the loss of macrophytes (seagrasses and perennial algae) through trophic cascades. There has also been a ten-fold increase in deoxygenated dead zones over the last century, driven by nutrient runoff and eutrophication and reinforced by phosphorus recycling from sediments.

Some nature positive change has already happened through the return of top predators, coordinated fisheries management, and reductions in nutrient loading. But the latter has suffered systematic delays and been thus far insufficient to positively tip away from eutrophication and dead zones (Varjopuro et al., 2014). Achieving a larger-scale positive tipping point for nature would benefit from positive tipping in diets (Box 3.5.1), reducing the demand for intensive agriculture on land and associated nutrient loading (as well as demand for fish). Already Denmark, for example, has revised dietary guidelines and is implementing new agricultural taxes. Reducing nutrient loading also requires institutional change in the Common Agricultural Policy (CAP) and its enforcement. This would benefit from coordination among multiple stakeholders including policymakers, farmers, environmental groups and consumers (Mennig, 2024).

Positively tipping resource recovery

The recovery of natural resources can be positively tipped either through triggering ecological tipping points or through social tipping points that transform resource stocks. The combination of some of these actions with some of those noted above (3.5.2.1) have the potential to positively tip recovery of larger scale systems – for example, the Baltic Sea (Box 3.5.3).

Reduce overfishing. The recovery of collapsed pelagic fish stocks can be positively tipped by enforcing a Maximum Sustainable Yield (MSY) – the highest yield that can be taken without significantly affecting reproduction. This typically requires short-term reduction in fishing effort, which in turn requires strong regulatory enforcement and punishment of those who do not comply. Enforcement of MSY has already positively tipped recovery of plaice and hake stocks in the North Sea (Blöcker et al., 2023), although recovering cod stocks will also require controlling sprat stocks (Sguotti et al., 2019).

Marine protected areas. For coastal fisheries, marine protected areas (MPAs) can positively tip fish stock recovery, by providing safe spawning areas and 'spillover' of fish into the surrounding waters (Di Lorenzo et al., 2020). MPAs can be particularly effective on coral reefs as these naturally support transient fish spawning aggregations (Russ et al., 2004). Successfully establishing MPAs requires careful engagement with fishing communities. (Russ et al., 2004).

Promote community governance of common pool resources. Societies can positively tip into cooperating to recover common pool resources (Castilla-Rho et al., 2017). For example, reinstating the traditional practice of maintaining artificial reservoirs that capture the monsoon rains has recovered depleted groundwater resources in drier parts of India (Everard, 2015). The rains infiltrate to recharge groundwater that in turn support natural vegetation, agriculture and the community. Cooperative village level governance of water resources was key to this.

Positively tipping the spread of nature positive initiatives

The spread of nature positive initiatives, including nature-positive farming (Box 3.5.4) and some conservation and regeneration initiatives can be positively tipped by reaching a critical mass at which one more person or group adopting can trigger a phase of self-propelling adoption in a population. Adoption can be further amplified by increasing returns whereby adoption becomes more attractive the more who adopt (e.g. because costs decline and benefits increase).

Ensure benefits to locals. Benefits to local people are critical to achieving positive tipping of diffusion for conservation and agroforestry initiatives (Mascia and Mills, 2018). For example, they determine the relative scaling up success of different community-based forest conservation initiatives in Tanzania. Benefits to smallholder farmers, including carbon payments, helping alleviate household credit constraints, economically empowering women, are key to the rapid spread of The International Small-Group and Tree Planting Program (TIST) in East Africa and India (Emenyu et al., 2023). It in turn greens the surrounding landscape (Buxton et al., 2021).

Promote community management. Community management is key to positively tipping the spread of sustainable resource management. It governs the spread of locally managed marine (protected) areas (LMMAs) across Pacific islands (Mascia and Mills, 2018). Community-based groundwater management has spread widely across Asia, improving productivity by up to 250 per cent. Modelling can forecast where there is greatest potential for further rapid scaling of adoption – for example, of LMMAs in the Solomon Islands (Clark et al., 2024).

Leverage moisture recycling. The spread of revegetation efforts can leverage natural moisture recycling (van der Ent et al., 2010). Evapotranspiration from regenerating vegetation supports precipitation and vegetation growth downwind. This is particularly important for precipitation in the western Amazon and La Plata basins (Zemp et al., 2014), the Congo basin (Worden et al., 2021), agricultural areas of sub-Saharan Africa (Nyasulu et al., 2024), and the Tibetan plateau (Y. Li et al., 2023) – suggesting regions where revegetation efforts would promote their own spread.

Together, reducing drivers of nature loss and activating positive tipping mechanisms of ecosystem restoration, resource recovery, and spread of nature positive initiatives, have the potential to positively tip the larger-scale recovery of degraded biomes, such as the Amazon rainforest (see Box 3.5.5 and 4.1 Amazon Case Study).

Box 3.5.4: Scaling nature positive farming

Nature positive farming methods prioritise efficient and effective use of natural resources for farming while providing benefits for society, the environment and biodiversity. Widespread adoption of such practices could reduce inputs, protect nature, and increase the health and resilience of ecosystem service provision in agro-ecosystems.

Diffusion and contagion can be observed for various models of nature positive farming across the world, from adoption of digital and smart farming technologies particularly in industrialised farming settings (Long, Blok and Coninx, 2016; Shang et al., 2021; Giua, Materia and Camanzi, 2022), to the spread of a suite of practices among smallholder farmers in the global South, including minimum-tillage, conservation agriculture, agroforestry, intercropping and natural pest control according to different farming contexts (Kassam, Friedrich and Derpsch, 2019, 2022; Emenyu et al., 2023; Olabanji and Chitakira, 2025; Spurk et al., 2025). More detail on factors that enable or slow adoption of these practices is given in Chapter 3.3.

Policy actions:

- Facilitate financial access, subsidy and incentives, including through strengthening and regulating markets for ecosystem service provision (Hilmi et al., 2024; Baker et al., 2025).
- Set clear, measurable targets through design of metrics and monitoring frameworks (HLPE, 2019; Baker et al., 2025).
- Engagement with farmers, respect for values and motivations, recognising them as crucial agents of change: ensure participatory approaches are adopted to facilitate collaboration and cooperation (Baker et al., 2025), and to develop targeted interventions that are sensitive to landscape and cultural context (Olabanji and Chitakira, 2025).
- Design and implement schemes at landscape (rather than farm) scale (HLPE, 2019; Baker et al., 2025).

Box 3.5.5: Tipping recovery in the Amazon Rainforest

The Amazon rainforest is at risk of tipping to degraded forest or dry grassland states at large scales, through a combination of deforestation and other local pressures, climate change, and biophysical amplifying feedbacks (see 4.1 Amazon Case Study, Boulton, Lenton and Boers, 2022; Flores et al., 2024; Brando et al., 2025). The drivers of deforestation are complex and cross multiple scales; local, domestic, regional and international, but include cattle grazing, expansion of soy production, land speculation, mining and illegal land grabs. Yet the Amazon's resilience also offers pathways to self-propelling recovery.

Joined up action across scales to effectively protect forests and forest communities, and stop deforestation, could enable planting and natural regeneration to positively tip large-scale forest recovery. By understanding the ecological, biophysical and fire feedbacks that drive tipping between forested and dry grassland states, particularly in the southern Amazon (see 4.1 Amazon Case Study), interventions can be designed to maximise their potential to trigger positive tipping to restore forest cover (also see Chapter 1.2, Box 1.2.6). For example, reforestation efforts can consider localised geometry to maximise the resulting destabilisation of the grassland/pasture state (Wuyts and Sieber, 2023). Regions can be targeted for regeneration based on their contribution to moisture recycling and wind patterns to maximise longer range benefits (Boers et al., 2017; Wunderling et al., 2022).

Such spatially coordinated action would benefit from tipping cooperation among relevant actors, for example through inclusive governance approaches that ensure protections and opportunities for local communities, provide incentives for and ensure compliance by commercial actors, and align with national and international policy (Amazon case study 4. & 5.)

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