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Channeling diverse innovation pressures to support European sustainability transitions

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Channeling diverse innovation pressures to support European sustainability transitions

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1. Introduction

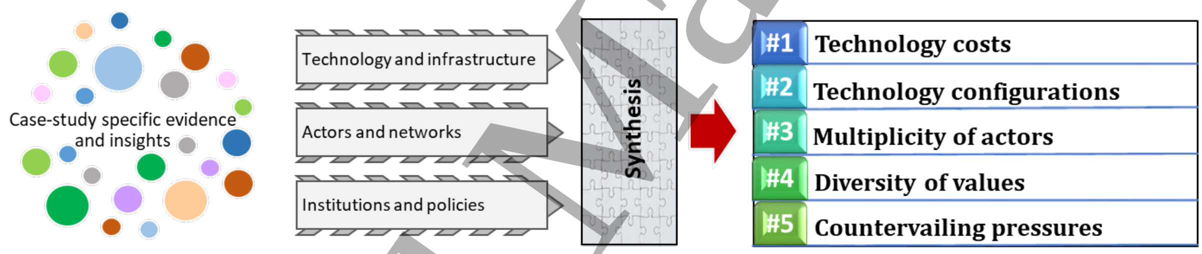
In light of pressing climate mitigation needs and commitments, swift and strategic action is required to reorient and accelerate technological transitions towards an economy compatible with the goals of the Paris Agreement. More generally, a consensus is emerging that innovation patterns and processes must be commensurate to our growing sustainability challenges.[1] In this Perspective, we show how technological innovation systems are being harnessed to address key decarbonization challenges in Europe. Specifically, we illustrate five recurring lessons on how technology costs and configurations, as well as actors, values and countervailing pressures, influence the development and diffusion of the most promising technologies for the decarbonization of agriculture, buildings, electricity, information and communication technologies (ICT), industry and transport.

These lessons emerged from comparative case studies in Germany, Italy, Poland, and the United Kingdom (Figure 1 top panel).[2] These countries were selected to represent a diverse mix of national contexts, geographic locations, and energy regimes and to span a range of innovation system configurations and dynamics, each facing unique set of specific challenges and strengths, but across which common themes may be recognized. The comparative case studies were carried out using a common, consistent analytical framework informed by different innovation system approaches and concepts, such as national innovation systems, sectoral innovation systems, the functions of technology innovation systems, and the literature on sustainability transitions (see Figure 1). More details about our analytical framework are offered in the Supplementary Material "Annex I: Framework for Case Studies of National and EU Innovation Systems."

The strength of this overarching summary and illustration lies in the fact that, while it is easy to argue that innovation must play an essential role in the transition towards sustainability, it is much more challenging to provide useful models for how policy may help in mobilizing innovation for this purpose.[3] Real-life lessons learned can (and should) be key inputs into national and EU policy making to ensure that all the key elements of the low-carbon innovation system are successfully mobilized. More details of our case studies and the underlying data for this Perspective are offered in the Supplementary Material "Annex II: Further case study data in support of our analysis."

Figure 1: Technological, geographical, and analytical case study selection for the Innopaths Project

	Agriculture	Buildings	Electricity	ICT	Industry	Transport
Germany	Cattle Diet Management	Building Envelops for new buildings	Solar PV	Electricity Smart Meters	Energy Management Chemical & Petrochemical	Battery Electric Vehicles
Italy	Biochar				Energy Management Steel Industry	
Poland	Biochar		Wind		Energy Management Chemical & Petrochemical	Light Rail Rapid Transit
UK	Cattle Diet Management				Energy Management Steel Industry	



Source: Authors

<u>2. Lesson 1: Varied technological configurations can respond to local needs but also hinder diffusion</u>

Technology solutions must respond to local conditions and contexts.[4] Indeed, in most sectors, several technological configurations for decarbonization at different levels of maturity are available. For instance, some configurations of renewable power technologies are extremely novel, such as deep-water or floating offshore wind farms, or bifacial or heterojunction solar cells. Similarly, several different smart meters are available, as are varied designs of high-efficiency building envelopes, which have been demonstrated and applied for several years; mitigation strategies regarding livestock feeding range from ensuring forage quality and precision feeding, which are considered a best practice, to the use of essential oils and tannins as additives to forage, which has been demonstrated but is not yet widely promoted or diffused.

Yet, the availability of different technological configurations plays a dual role in low-carbon innovation systems. On the one hand, alternative configurations allow technology to be applied within different geographical, social, economic, and institutional environments. Indeed, certain approaches and technologies for livestock management that are deployed in countries like Australia are not directly relevant for European countries, in which the majority of livestock does not graze in large and dispersed pastures. Similarly, energy efficient building envelopes need to adapt to local climates.

On the other hand, the continuing presence of competing technological configurations, a common characteristic of early-stage diffusion into niche markets before the emergence of a dominant design, may represent a barrier to successfully promoting more widespread diffusion of certain low-carbon technologies. As illustrated in Annex II, section 2 of the SI, this characterized the roll-out of smart meters in Poland. There, smart meeting installations has so far been driven by voluntary initiatives by distribution system operators (DSOs). The lack of a single or commonly-agreed model or technological characteristics led to difficulties with interoperability. Similarly, in the UK, more than fifty energy suppliers utilize dozens of different smart meter models.[5] In Germany, a lack of clarity around standards and certification of the smart meter "gateway," which enables communication between smart meters and local devices, and with third parties (e.g. grid operators and utilities), was a key factor preventing widespread diffusion (see Annex II, section 2 of the SI for more details).

3. Lesson 2: competitive technology costs are a necessary but insufficient enabler

Alongside technology costs,[6] other major factors affect the diffusion of (low-carbon) technology. One of such factors is, for instance, the presence of tailored and flexible environmental policies.[7] For instance, in the diffusion of wind technologies, policy learning played a crucial role alongside material costs and learning-by-doing. The increasing use of competitive auctions to provide subsidy support was accompanied by a substantial reduction in (revealed) costs for new onshore and offshore wind installations in a number of European countries, including the UK. Properly designed auctions for more mature technologies provide both stable revenue streams for developers and investors and better value to the public purse, promoting further deployment.[8,9]

Along similar lines, cost-effectiveness did not lead to fast and widespread diffusion of smart meters and high efficiency building envelopes in most instances. Smart meters, along with the surrounding infrastructure (data transmission and processing, communication technologies etc.), have reached a stabilization phase. As illustrated in Annex II, section 2 of the SI, the large-scale roll-out started in Italy in 2001; at the end of 2017, smart meters had reached more than 50% of households in nine Member States, with five Member States having no large-scale installation program. While the technology is fully commercialized and the European market is growing, traditional metering solutions still account for a substantial proportion of national markets. As discussed below, in many countries the diffusion of smart meters is still fragmented, for reasons which include the interoperability between different configurations/operators, lack of stringent national requirements, and/or the lack of clear standards for the management and operation of the IT infrastructure associated with smart meters.

Another important factor affecting the diffusion of cost-competitive low-carbon technologies is the cost of supporting infrastructure, as illustrated by renewable electricity generation technologies. The key role of transmission infrastructure when renewable resources are geographically clustered and far from centers of demand is widely recognized. As discussed in Annex II, section 2 of the SI, this is the case, for instance, for offshore wind in the UK: challenges could soon arise if substantial offshore generation capacity connects with the onshore transmission network at a small number of specific points. Yet, building transmission infrastructure (either national or in coordination with other countries) to fully exploit offshore wind potential is expensive, increasing the total cost of delivering electricity from offshore wind to the market.

4. Lesson 3: A diversity of actors shapes technological transitions

A successful technology transition requires the concerted action of a diversity of actors—state and non-state—at multiple scales—local, national, and supranational— to shape innovation and transition dynamics. Elinor Ostrom termed this “polycentrism” as it blends action across spatial levels but also involves a multiplicity of organizations and actors.[10]

The key role of polycentrism in promoting technology innovation and diffusion emerged from all the INNOPATHS case studies. For instance, it is clearly visible, in low-emission livestock management technologies and approaches in the UK and Germany. Both countries invested heavily in fostering research (in part through international collaborations) to study feed type and feed management as a promising way to reduce GHG emissions from agriculture. Agronomists and engineers undertaking academic research on biochar collaborated with entrepreneurs, generating fruitful synergies. National and regional biochar associations, the most well-known of which is the International Biochar Initiative, were central in bringing together different stakeholders, acting as knowledge hubs and, in developing and administering voluntary certification schemes helping facilitate diffusion.

The comparatively more successful deployment of high-efficiency envelopes for new residential buildings in Germany as opposed to other EU countries also reflects synergistic interactions between diverse actors and scales of governance. The Federal and regional (Länder) governments both played important (and potentially decisive) roles in a variety of ways, alongside other public bodies, such as the KfW (and more local iterations, the Länderbanks) and public research institutions. A collaboration between what became the independent Passive House Institute and the Hessian Ministry for Economics and Technology first developed and demonstrated the Passive House concept in the early 1990s. The KfW, a national public interest bank, has been crucial in encouraging the diffusion of high-efficiency envelopes for new buildings, through the long-time provision of various well-designed (and well-used) subsidies. All the main German associations representing stakeholders in the construction and housing sector, including landlords, all support stringent energy-efficiency requirements for new buildings, and actively promote and develop high- construction technologies, techniques and skills, often in collaboration with publicly-funded institutions.

Yet, innovation is an international process. For instance, the dynamics unveiled in the electric vehicle (EV) case studies clearly go beyond national and European borders. Success in the diffusion of BMW and FIAT battery EVs can be ascribed to a supportive policy and institutional environment in California shaping strategic decisions made by European automotive manufacturers, as well as the availability of technologies such as carbon-fiber-reinforced-plastic availability from a strategic venture with SGL and battery assembly and manufacturing opportunities in China, Japan, and South Korea.[11] The role of international actors is also very apparent in the case of efficient livestock feeding: the most extensive experimentation is being carried out outside the EU, and particularly in Australia

Several case studies also showed how, when polycentrism is weak, or worse, lacking, low-carbon technologies do not develop and deploy successfully, therefore hampering sustainability transitions are hampered. This is the case for light rail transport in Poland, which lacks any real support beyond a single pilot project,[12] for the deployment of high-efficiency envelopes for new residential buildings in Italy, Poland and the UK, which largely failed due to the centrality of power and the inability or unwillingness of many actors to engage in low-carbon innovation and technology diffusion (see Annex II, section 3 of the SI).

5. Lesson 4: A plurality of values shapes the EU innovation system

Value systems play a key role in shaping the way innovation objectives and priorities are framed.[13] Several examples of the diverse range of values and rationales underlying innovation dynamics emerged from the INNOPATHS case studies, including how values support successful innovation and diffusion of low carbon technologies.

For instance, commitment by several actors and local bodies to accessible but low-impact mobility (underpinned by values of affordability and sustainability) was one of the key success factors in the DLR case study as well as in the successful diffusion of EV cars.[11,12] This is even more apparent in the case of high building envelops in Germany, as illustrated in Annex II, section 4 of the SI. Awareness of climate and energy-related issues (values of sustainability), the vision and expectations for the Energy Concept, and their implications for the buildings sector – including the need for high-efficiency envelopes for new buildings (values of efficiency) – were strong and shared by all key actors. These include the three principal German trade associations for the construction industry, the Federal Chamber of Architects and trade associations for skilled building crafts and social and professional landlords, and representatives for tenants, are also publicly in favor of high-efficiency buildings. Similarly, around 800 Solar Photovoltaic Energy Cooperatives in Germany played an important role in supporting PV from the community level. The values here appear to be a mix of sustainability, community cohesion and self-sufficiency.

On the contrary, the public perception of certain practices and feeding strategies relating to livestock management, such as additives, or vaccination, is far from being consistently positive (in part due to health concerns from the consumption of treated animals or their products), and may indeed prove to be a particularly hard-to-overcome barrier, as it would require widespread education and information campaigns to overcome perceptions. Thus, even if technologies are available, cheap (or subsidized) and ready-to-deploy, the relevant actors may still refuse to accept and adopt them.

6. Lesson 5: Countervailing pressures often slow and block innovation

Entrenched interests and lobbies can threaten the development and deployment of alternative, low-carbon technologies and innovation systems; in this context, European-level actors, policies and institutions play a crucial role in providing an impulse for the low-carbon transition.

For instance, industry lobbies play a key role in slowing the diffusion of renewable electricity. In Poland, the high level of state ownership in coal mining and electricity generation give this fuel and technology a particular political strength that is difficult to displace. Even in Germany, where support for renewables is widespread, the coal sector has considerable influence due to the high level of employment it supports.

Large energy companies with vested interests remain responsible for the vast majority of electricity generation in all countries. Yet, in Germany the share of the largest four companies dropped from 95% of total electricity generation in 2004 to 76% in 2015 due to the strong growth of renewables and distributed generation with 47% of energy-intensive firms producing their own electricity[14,15]. In Poland, five companies (PGE, TAURON, EDF, ENEA and PAK) provide about three quarters of generation; the biggest three of which (PGE, TAURON and ENEA) account for more than half of electricity generation, and are state-owned. Furthermore, four out of five mining companies are fully or partially state-owned. Through this ownership, the state has a financial stake in the survival of coal power plants[16]. In contrast, wind accounts for less than 7% of electricity production; wind farms are small, and only 19% of wind generation capacity belongs to state-owned utilities.[17] Campaigning groups have a role, including those that campaign against wind turbines. Such groups have had substantial impacts on diffusion and related policies in both UK and Poland. In the UK the focus of objections has been typically on the aesthetic impacts on the landscape, whilst in Poland turbines have sometimes been associated with moneymaking schemes of corrupt landowners,[18] or with non-national elements, as argued above.[19]

Governing parties and coalitions hostile to the decarbonization process can inhibit the effective operation of innovation systems regarding low-carbon technologies. A largely hostile Italian government led by the Five Start Movement and the Lega Lombarda in Italy in 2018 failed to effectively implement and monitor an otherwise comparatively advanced national regulation regarding energy efficiency with respect to other countries. Few Italian regional governments implement more stringent minimum energy performance requirements for new residential building envelopes than the central government requires, and some had no minimum requirements prior to 2005, when the initial EU Energy Performance of Buildings Directive came into force in Italy. No subsidies for energy-efficient new construction have been available at the national level (except briefly in 2010), and few from regional governments.

The Polish institutional, policy and political environment (from national to local level) is generally hostile to ambitious climate and energy policy, with similar consequences. Private car and other road-based passenger mobility are encouraged at the expense of alternative modes, such as light rail transport[16]; and support for the deployment and high-efficiency envelopes for new residential buildings is weak. Housing policy in Poland is governed by the Ministry of Investment and Development, with energy efficiency policy largely the remit of the Ministry of Energy. Although local authorities are responsible for granting construction permits and ensuring compliance with building regulations, they are not permitted to set standards that exceed national requirements (except with regard to heating technology, as they pertain to local air quality). Poland has a national public interest fund (NFOSiGW), with an explicit focus on environmental protection, however no funds are currently allocated to the construction of high-efficiency envelopes for new residential buildings.

7. Conclusion

This Perspective illustrates specific examples, drawn from comparative case study research, of how technology costs and configurations, as well as actors, values and countervailing pressures, influence the development and diffusion of the most promising technologies for the decarbonization of agriculture, buildings, electricity, information and communication technologies (ICT), industry. and transport. Such lessons are important to inform policy making on ways to effectively harness and promote innovation for the low carbon transition.

An important first insight emerging from our cross-country, cross-sector case study approach is that a given country may have successfully supported the diffusion of a given technology (e.g., a smart meter), but may be lagging behind with respect to another technology (e.g., more efficient agriculture or lower carbon mobility). In other words, no country emerged which was successful at promoting all technologies analyzed. Crucially, the decisions to switch to low-carbon technologies are often made with multiple objectives, and a strategy that is optimal in one context may not be in another. This highlights the complexity of supporting the transition towards a climate-neutral economy.

A second major insight is that, in this context, EU institutions and policies provide an important framework fostering the transition towards low-carbon economies. Institutions and policies play a key role in supporting polycentrism and the convergence of technologies, actors and policies in support of the various low-carbon transitions explored. In those sectors where a European framework and targets are in place (as for example in the case of renewable energy), the impact of countervailing pressures, including those of vested interests, are significantly reduced. Thanks to the presence of European level commitments towards the low-carbon economy, opposing actors in a given country or sector can only (significantly) slow the process, but rarely can they completely kill it.

Conversely, when such a EU-framework or targets are missing, as in the case of biochar technologies or smart meters, it is comparatively harder for technological configurations to emerge, and opposing interest may halt the development and diffusion of specific low-carbon technology options. This suggests the importance of promoting EU level concerted action, targets and legislations for all those (low-carbon technologies) which can support the energy transition.

A third important insight relates to the role of stakeholders. Getting the support from a broad base of stakeholders can accelerate decarbonization efforts significantly. For this reasons, polycentrism should be fostered through approaches promoting the engagement of citizens, workers, businesses and industries also at the national and sub-national levels. This sheds light on the importance of the stakeholder engagement process which has been pursued at the European level to increase the acceptability of the low-carbon transition. This is an important avenue to ensure the diffusion of low-carbon technologies.

Taken together, our analysis underscores how multi-criteria policymaking, strong institutional frameworks, and polycentric forms of governance can shape innovation pressures compellingly towards—or against—decarbonization.

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