

Energy/Propulsion in the East Midlands

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Case Study Overview

Characteristics and history: The propulsion cluster in the East Midlands is centred on Derbyshire and Nottinghamshire. “Transport equipment”, which covers the production of aerospace, automotive, and rail transport vehicles, is a very important sector for the whole of the East Midlands, since it is the second largest manufacturing sector in the region (Make UK, 2022). Particularly for Derbyshire and Nottinghamshire, the Transport Equipment manufacturing sector is 40% more productive in this area than elsewhere in the UK, hosting a large number of globally significant employers (Department for Education, 2017). Derbyshire and Nottinghamshire place a strong emphasis on their low carbon economy, as shown by their increasing R&D Investment in Low Carbon and Environmental Goods and Services (LCEGS), with the Alternative Fuels sub-sector performing significantly above average in terms of market size and the Nuclear sub-sector showing stronger growth than the UK average (D2N2, 2021).

The area is historically connected with Britain's Industrial Revolution as some of the country's first factories and mills were located there. Additionally, Derby has always been important for the railways: the Derby Locomotive Works started building steam engines there in 1840, and the nationalised British Rail located its R&D department there. Moreover, it hosts the largest concentration of Rolls-Royce employees in the UK; a community that settled in this region before World War I. In addition, Derby has always been a railway hub.

There is a strong innovation and manufacturing cluster around propulsion and engine systems engineering that contributes to sectors related to transport. In particular, there is significant expertise concentrated in this region in the automotive, rail, aerospace, and nuclear-powered submarine industries, creating interconnected sub-clusters within the broader propulsion cluster. To support the activities of these industries, an important number of firms have centred around this area, supplying propulsion equipment, transport equipment, maintenance services, and more. Interviewees stressed the high level of talent and expertise of employees concentrated in the region, an argument supported by the high salaries observed in districts in Derby (Department for Education, 2017).

Geography and size: Arguably, the propulsion cluster in Derbyshire and Nottinghamshire is part of a bigger cluster that includes thousands of firms and extends to the whole of the Midlands. Some of the interviewees emphasised that as far as the automotive cluster is concerned, the West Midlands hosts a significant proportion of the innovation and manufacturing activities of the Midlands, including electric propulsion activities. However, although electrification ventures are also important in the East Midlands, Derbyshire and Nottinghamshire seem to be very well positioned to develop strong regional competitive advantage in the other alternative technologies, such as hydrogen, nuclear, and alternative fuels, specialising in providing efficient low-carbon energy solutions for trains, aerospace, submarines, and vehicles.

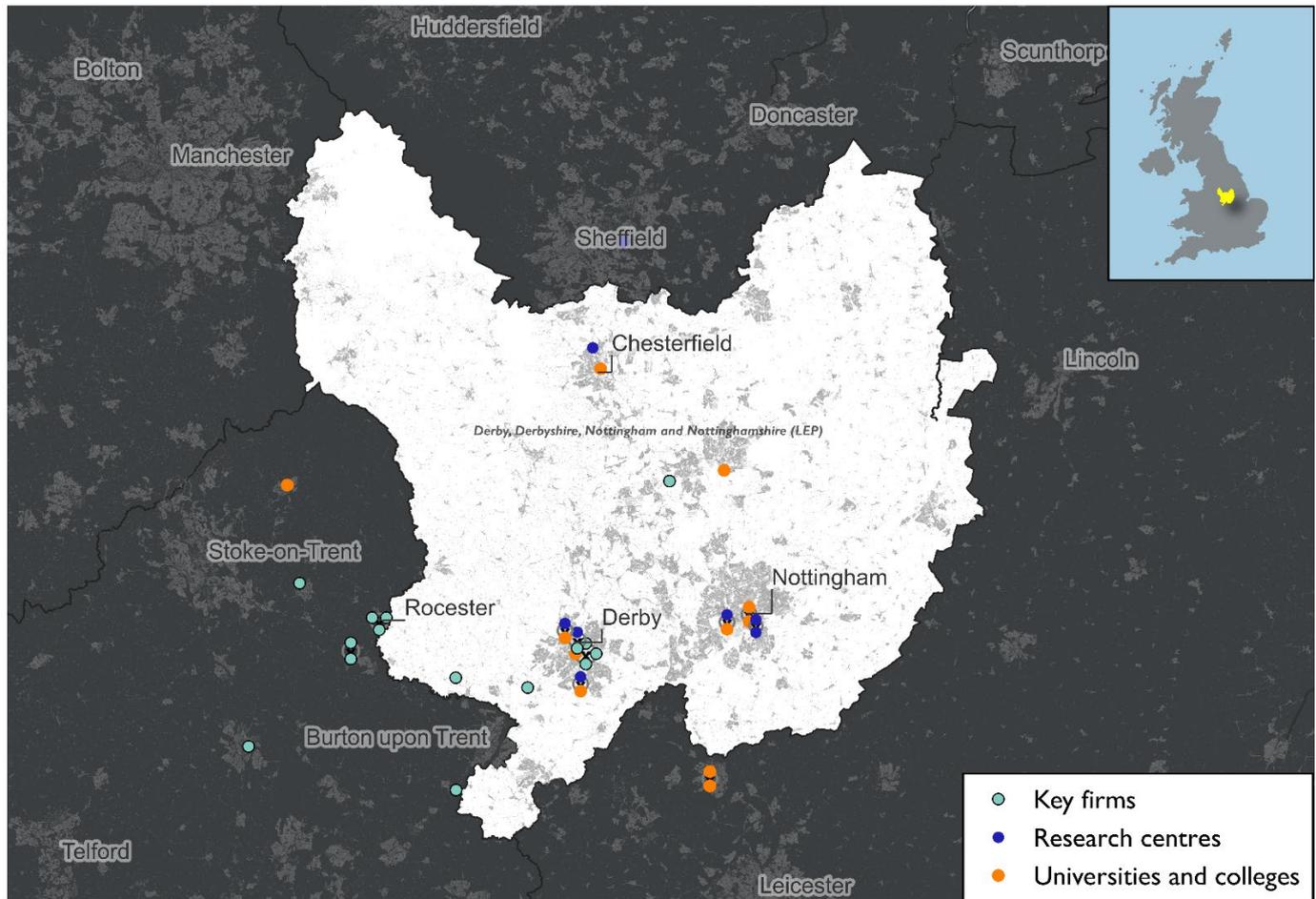


Figure 1: Energy/Propulsion in the East Midlands map.

Areas of potential future growth: Interviewees unanimously agreed that the cluster’s innovation activities primarily focus on developing technologies that will contribute to the decarbonisation of transport (i.e., low-carbon transport). To achieve this goal, a series of alternative technologies has started to replace internal combustion engines, with each technology at a different stage of development and diffusion and in a different field of application. Electric propulsion is definitely the primary alternative technology, and its level of development and diffusion reveals that it is already too significant to be overtaken by other technology in the near term. As one interviewee eloquently noted, “the train of electrification has already departed”. Apart from activities related to electrification, important investments have been made in this region in other technologies such as hydrogen, fuel cells, biofuels, and nuclear energy (i.e., nuclear reactor cores for submarines). More specifically, interviewees emphasised the above-average concentration of innovation and manufacturing activities related to hydrogen. All major private companies working in propulsion have dedicated significant resources to hydrogen (e.g. Alstom, Toyota, Rolls-Royce, JCB), as, in certain applications, such as long-distance journeys with trains, aviation (where batteries could be too heavy), or heavy vehicles, the use of hydrogen seems very promising. According to interviewees, other satellite sub-clusters that could affect the growth of the propulsion cluster are the digital smart control systems relevant to energy management and the electric charging infrastructure and systems. Finally, there was a strong consensus that synergies and complementarities among the propulsion technologies can substantially boost the overall growth of the cluster as well as the export potential for the region, contributing to national and international energy transition objectives.

Reflections: The propulsion cluster in the East Midlands, centred around Derbyshire and Nottinghamshire, is an established cluster since important anchor firms have been active in these regions for decades (e.g., Rolls-Royce, Alstom, Toyota). However, the green industrial revolution has brought a new dynamic to this area. Due to the fact that within these regions, a variety of cutting-edge low-carbon technologies (e.g., electric, hydrogen, alternative fuels, nuclear) are being developed, serving multiple sectors of the economy (e.g., trains, vehicles, aerospace, submarines), a strong regional absorptive capacity has been created in energy research in general, and in propulsion and engine systems engineering, in particular. Apart from knowledge synergies currently achieved among these technologies, this area is competitively positioned to successfully adapt or even lead the way to any potential technological trajectory of energy systems that may emerge in the medium-to-long term.

Core Assets

Market structure and anchor firms: Some of the most important global firms in the propulsion industry operate within the Derbyshire and Nottinghamshire propulsion cluster.

Rolls-Royce - this firm's long-lasting presence in Derby can be considered as a primary catalyst for the cluster. According to the 2022 EU Industrial R&D Investment Scoreboard (Grassano et al., 2022), Rolls-Royce was the fifth R&D spender globally in the Aerospace & Defence industry, spending €964.3 million in R&D in 2021. Derby hosts the largest concentration of Rolls-Royce employees in the UK and its academy recruits over 200 apprentices each year. The primary innovation and manufacturing activities of Rolls-Royce within Derby relate to civil aerospace and nuclear reactor cores and propulsion components for the Royal Navy's nuclear submarines.

Alstom (formerly Bombardier) - Derby hosts Alstom's activities related to the design and manufacture of its trains. Alstom, as a leading global player in the Industrial Engineering industry, spent €585 million in R&D in 2021 (Grassano et al., 2022), with significant resources spent on low carbon technologies to power trains, including hydrogen and battery solutions for sustainable transport on non-electrified lines.

Toyota - has been active in this region since 1989. Toyota's manufacturing plant, located in Burnaston, Derbyshire, is one of the UK's largest vehicle manufacturing plants. Toyota is the largest Japanese R&D spender and the fifteenth R&D spender worldwide, with €8,691 million in R&D expenditures in 2021 (Grassano et al., 2022). Apart from electrification, Toyota is investing heavily in hydrogen technologies.

JCB - is located in Staffordshire next to Derbyshire, and is a major construction vehicle manufacturer with important investments in hydrogen, electric motors, and hydrogenated vegetable oil and with €98.2 million spent in R&D in 2021 (Grassano et al., 2022).

Other noteworthy firms related to the cluster are Porterbrook, a rail network company located in Derby, Caterpillar's Stafford-based facility for the manufacture of the company's largest and most powerful diesel engines, and Horiba Mira in Nuneaton Warwickshire, a global provider of automotive engineering, research, and test services.

Higher education and training institutions: Derbyshire and Nottinghamshire host three important universities and several further education colleges. All three universities seem to acknowledge the history and potential of the region generally in engineering and, particularly, in aerospace, automotive, and rail, providing many undergraduate and postgraduate programmes and research activities within these fields.

The **University of Nottingham** offers highly ranked studies in Aerospace, Electrical and Electronic Engineering, and Mechanical, Materials and Manufacturing Engineering. Concerning its research activity in the relevant fields, the University of Nottingham is home to the Institute for Aerospace Technology, a major centre for aerospace research, where researchers and academics in collaboration with private companies strive to produce useful knowledge in the fields of aerospace electrification and future propulsion. Additionally, the university hosts the **Power Electronics, Machines and Control Research Group**, an internationally renowned research group in Electrical and Electronic Engineering, delivering influential teaching, research, and industrial collaborations in subject areas such as Power Electronic Systems, Electrical Machines, Electrical Motor Drives and Systems, and Power Electronic Integration.

The **University of Derby** offers high-quality undergraduate and postgraduate studies in Electrical and Electronic Engineering, Mechanical and Manufacturing Engineering, and undergraduate courses in Motorsport Engineering. It hosts the **Rail Research and Innovation Centre**, which provides collaborative research and innovation projects within the Derbyshire and Nottinghamshire rail supply chains and access to its facilities that address infrastructure related to rail composite design and manufacture, rail data analytics and artificial intelligence, and decarbonisation rail solutions. Another relevant research centre within the University of Derby is the **Institute for Innovation in Sustainable Engineering (IISE)**, which focuses on issues related to sustainable engineering solutions across various business sectors, placing important emphasis on the regional dimension of their research impact.

Finally, **Nottingham Trent University** also offers undergraduate and postgraduate studies in Engineering, including Aerospace Engineering, with important research output in sustainability and low carbon strategies.

Other research and anchor organisations: Derbyshire and Nottinghamshire regions are home to some nationally important organisations that significantly contribute to the development of the cluster. The most noteworthy are:

- **The Energy Research Accelerator:** an Innovate UK- funded organisation that brings together universities, the government, and industry to develop low carbon technological innovations.
- **The Low Emission Vehicle Enterprise and Learning Network**, which delivers skill development, knowledge transfer, and business networking in low carbon transport technologies.
- **The Nuclear Advanced Manufacturing Research Centre (Nuclear AMRC):** part of the Catapult network, Nuclear AMRC is a centre led by industrial members to support companies in the nuclear sector to develop and test new technologies and to be better networked.

Support structures and infrastructure: Nottinghamshire County Council, Nottingham City Council, Derby City Council, Derbyshire County Council, D2N2 LEP, Low Carbon Business Network, East Midlands Chamber Sustainability Forum, Midlands Engine's Green Growth, and the Midlands Net Zero Hub are all aware of the importance of this cluster for the region, and strive to contribute to the transition to a low carbon economy by working with and educating local businesses, developing appropriate business networks, facilitating and supporting investments in energy projects, and coordinating the various stakeholders that could exert an influence on the cluster's dynamic. Moreover, the Rail Forum, a national industry body that provides networking opportunities to its members who belong to the whole rail industry, is located in Derby.

The most important infrastructure related to innovation that can be used by the firms of the cluster in the region is the shared infrastructure of the local universities. Most noteworthy are the shared infrastructure of the **Rail Research and Innovation Centre** and **Institute for Innovation in Sustainable Engineering** at the University of Derby and those of the DER-IC (Driving the Electric Revolution Industrialisation Centres) and **Institute for Aerospace Technology** hosted at the

University of Nottingham. Additionally, the Nuclear AMRC is building a new research facility on Infinity Park, Derby, focusing on the later-stage development of new technologies related to the nuclear supply chain. Finally, we have to refer to two important energy projects that could prove to be game-changers for the region in the long run. The first is the East Coast Hydrogen launched in North East England which will give the ability to Derbyshire and Nottinghamshire to pipe in green and blue hydrogen from the coast by 2030. The second is the fusion power plant that will be constructed at West Burton, Nottinghamshire, and will be the first commercially feasible fusion power station. This project, expected to be operational by early 2040, though not considered as directly related to propulsion, will attract the best engineers in energy systems worldwide, probably leading the knowledge capacity of the region in Energy Engineering to the highest levels.

Finance: With respect to finance for growth or innovation, interviewees felt that, in general, firms have relatively good access to finance. However, a large portion of this finance comes from the government while private equity financing seems to prefer the Golden Triangle (i.e., Cambridge, London, Oxford) to the East Midlands. Nevertheless, a series of initiatives is in motion within the region that will facilitate access to better and easier finance, targeting primarily at SMEs and start-ups, which typically face greater difficulties in securing finance than larger firms.

Reflections: Interviewees revealed no disagreements about the significance of the assets related to the innovation activities of the propulsion cluster in the regions of Derbyshire and Nottinghamshire. To emphasise the innovation potential of the cluster for the UK, one of the respondents that we interviewed from a university informed us that the first two UK beneficiaries of Horizon 2020 (the EU's research and innovation funding programme from 2014-2020) in the Green Transport Research category were Rolls-Royce and the University of Nottingham. Additionally, several interviewees underlined the presence of an important mass of SMEs, operating mostly around the anchor firms of the region. Finally, it is worth mentioning that according to a respondent, local universities are characterised by a higher degree of specialism in engineering (although lacking emphasis on nurturing university spin-offs), providing important collaborative, networking, and shared infrastructure opportunities to local SMEs.

Skills

Talent pool: Derbyshire and Nottinghamshire regions have a relatively large pool of skilled labour that can support the propulsion cluster. The main skills required are generally related to engineering, including mechanical, electrical, electronics, and systems engineering, while the most specialised engineering category is engine systems engineering. Other high-tech skills that are strongly related to industry needs are digital skills (including software development and cybersecurity) and data analytics. Concerning some other technical skills that are critical to the cluster, respondents emphasised shortages in welding and ultrasonic testing. Additionally, several interviewees stressed that although the region does focus on engineering skills provision, it still suffers from skills gaps in engineering. According to D2N2 (2021), the LCEGS sector (Low carbon and environmental goods and services) experiences significant skills gaps in production engineers and technicians in the region. Finally, some interviewees identified critical shortages in management and finance, skills that could facilitate the growth of the cluster.

Local skills provision: As already mentioned, local universities (i.e., the University of Nottingham, University of Derby, Nottingham Trent University) embrace the history and the potential of the

propulsion cluster in the region. This manifests in the high level of course offerings (accompanied by state-of-the-art facilities) in engineering, and extra attention devoted to aerospace, automotive, and rail, that have created a strong international reputation for propulsion and engine systems engineering. Additionally, the regional further education colleges (i.e., Derby, Chesterfield, Buxton & Leek College, Nottingham, and West Nottinghamshire Colleges) seem to take into account the regional competitive advantage in propulsion and engine systems engineering, making efforts to provide more relative skills. An important insertion into the skills production system will be the recently approved East Midlands Institute of Technology (IoT), operated by the University of Derby, Loughborough College, Loughborough University, and the Derby College Group. Another noteworthy addition to this endeavour is definitely the Nuclear Skills Academy, a partnership between the University of Derby and Rolls-Royce, supported by Nuclear AMRC, the National College for Nuclear, and other experts that started to operate in September 2022, offering more than 200 apprenticeships.

Reflections: There was a consensus among respondents that although the skills provision in the area for the cluster is important, it is inadequate to fill the existing gaps, a phenomenon that will increase in the future because technological change and industry needs evolve faster than educational, training, and academic transformations. Propulsion innovation activities are present worldwide and therefore, everyone competes for the same talents. Technological and climate change combined with an ageing workforce have resulted in significant shortages in skills that are related not only to engineers and scientists but also to technicians. Particularly for technicians, the gap is wider, a situation that calls for an upgrade of the role of colleges and apprenticeships in providing a relative workforce. Skills provision is a complicated economic and social process and, thus, a collaboration of all major regional stakeholders is required to improve it, leveraging mechanisms such as the identification and monitoring of the current and future skills needed for a low carbon economy (D2N2, 2019).

Knowledge Exchange

Firm research and development practices: As presented above, most of the R&D activities are performed by the anchor firms of the cluster: Rolls-Royce, Alstom, Toyota, and JCB. However, as one respondent stressed, it is important to differentiate Rolls-Royce and JCB from Alstom and Toyota, because the latter's R&D departments are not located in the region (i.e., Alstom and Toyota). These differentiations could have an important effect on the depth and breadth of knowledge and on the level of knowledge tacitness that resides in the region. In any case, the knowledge that arrives at their local premises from abroad is extremely important for the cluster.

Knowledge sharing and flows: Concerning knowledge sharing and flows, a conclusion that can be drawn from the interviews is that knowledge sharing among the cluster's firms is primarily realised through supply chain relationships. Other important channels of knowledge transfer are the numerous research collaborative projects orchestrated by the local universities and the collaborative, innovative, government-funded projects run by public organisations and local authorities (e.g., Innovate UK) that have achieved an important level of knowledge exchange among the participants.

Knowledge access and cultures: Some interviewees emphasised that, according to their perceptions, there exists a strong willingness for collaboration among the members of the cluster, acknowledging the importance of collaboration for innovation in high-tech sectors. Nevertheless, all the interviewees that expressed this kind of opinion were from an academic context, and, consequently, their opinion is mostly formed by the firms that participate in the universities'

collaborative projects. However, we cannot make any firm conclusions about firms' collaborative behaviour outside of the academic context.

Firm network relationships: It seems that the majority of firm network relationships can be considered supply chain relationships, having the anchor firms of the cluster as the central nodes of the network. Because of their long presence, their supply chain relationships could be better described as strategic partnerships, and this is particularly true for Rolls-Royce, due to the sensitivity of information around nuclear, which requires more stable firm relationships. Apart from these, the cluster's firms can be engaged in collaborative innovation activities through their participation in the local universities' research projects and the public organisations', local authorities', and support structures' networking initiatives, often backed by governmental funding.

Reflections: A significant amount of R&D expenditure is on propulsion technologies in the region, primarily coming from the anchor firms of the cluster. These anchor firms have created a structure of knowledge flows with other local companies, mostly based on supply chain linkages. Additional important contributions to the knowledge transfer within the cluster come from the universities' collaborative projects, the local authorities and support structure initiatives for networking and cooperation, and the government-funded collaborative projects. Nevertheless, we believe more collaboration and open innovation strategies are needed in order to cope with the challenges and uncertainties that characterise the rapid transition to a low carbon economy.

Networks of Coordination

Although a specialised organisation dedicated to the development of the propulsion network that might be perceived as a unified cluster does not exist, there are plenty of networks whose contribution is very important for the current and future potential of the cluster; for example, forums and alliances engaged in the development of the rail, aerospace, nuclear, and automotive sectors (e.g., Rail Forum, Midlands Aerospace Alliance) and networks related to low carbon economy (e.g., Low Carbon Business Network, Midlands Engine's Green Growth, Sustainability Forum of East Midlands Chamber, Midlands Net Zero Hub) and to productivity, manufacturing, and competition (Make UK, LEP's Manufacturing Advisory Panel). Additionally, city and county councils and the LEP also provide unquestionable support to all these kinds of activities.

Reflections: Most of the interviewees acknowledged a variety of associations across the different sectors are actively engaged in the region. However, as one respondent noted, there are so many diverse though complementary and reciprocally interrelated activities that are taking place in parallel in this area that the need for a coordinator that could lead the network is clear. This leader would ideally perceive the propulsion cluster as an interrelated, loosely or tightly coupled network of activities built on the knowledge base of propulsion and engine systems engineering that expands in every aspect of transportation and will establish an overarching narrative for the cluster, forming potential trajectories and venues for the future. The recently approved combined authority (Mayoral Combined County Authority) for Derby, Derbyshire, Nottingham, and Nottinghamshire could provide the opportunity for the establishment of a support structure that will lead the coordination and the whole propulsion cluster, aiming at transforming this area into a global centre for excellence in energy transition, adequacy, and efficiency.

Discussion: Innovation opportunities and support needs

Evolution and market opportunities: All interviewees agreed that Derbyshire and Nottinghamshire are uniquely positioned to play a central role in the research and development of propulsion technologies and engine systems engineering globally. The cluster enjoys deep and broad abilities and skills across all alternative propulsion technologies (i.e., electric, hydrogen, alternative fuels, nuclear), providing efficient low-carbon energy solutions for all means of transportation; that is vehicles, trains, aerospace, and submarines. The opportunities for the cluster could be characterised as more than great.

However, the uncertainty for the future of the cluster remains high. First, all the relevant technologies are still changing fast, have important challenges to deal with such as cost effectiveness, energy efficiency, and sustainable production (e.g., materials used in batteries). Second, the application of these technologies in the various types of transportation is to a large extent in flux and there are still a lot of important but unanswered questions concerning the right combination of the different technologies for all the possible cases of each means of transportation (e.g., long vs short journeys with airplanes, trains within vs outside of the electrical grid, micro-nuclear potential applications, heavy vs light vehicles, rural vs urban areas). Third, the level of infrastructure that could support the development of the propulsion technologies (e.g., recharging and refuelling infrastructure, grid expansion) is critical. Nevertheless, the cluster is gifted with some of the key industrial protagonists worldwide, which, combined with the contributions of a critical mass of SMEs, local universities, research centres, and support structures, creates a rich and strong ecosystem capable of confronting challenges emerging from technological, environmental, and social change as well as global competition.

Resilience: The most important vulnerabilities that the cluster must confront are common to the whole of UK manufacturing and are related to current and future skill shortages, supply chain difficulties, manufacturing costs, and energy prices. Additionally, as emphasised by several interviewees, it is of paramount importance for the region to provide a business environment conducive to entrepreneurship, innovation, and inward investments. Particularly for the propulsion cluster, as there is not yet any established technological paradigm for many applications, it is critical that the relevant actors have the ability to participate in the shaping of these paradigms, or at least to adapt to any potential technological trajectory that may prevail or emerge, avoiding lock-in situations while being open to global knowledge developments. Nevertheless, as one respondent aptly noted, as long as these particular big players remain in the region, their capacity signals a very optimistic outlook for the cluster.

Areas of potential support and intervention: Probably the most significant area of potential support concerns the strong and continuous commitment of the government to the potentiality of the cluster that can be achieved by long-term planning and by the formulation and implementation of policies based on evidence and dialogue among stakeholders. Interviewees also stressed the importance of establishing an organisation that could lead, coordinate, and coherently represent the cluster in its entirety, aiming at the elimination of fragmentation, overlapping, and barriers to information sharing, at the enhancement of collaboration, and at the creation of a shared identity among the cluster's members. For many of the respondents, the recently approved Combined Authority seems to be a great opportunity to undertake this coordinating role. Finally, it is worth referring to a respondent's opinion about possible interventionist initiatives, that there is a significant export potential for the cluster that is not capitalised on, and that, therefore, more support is needed for this.

Reflections: Although the road to efficient low-carbon propulsion solutions for each means of transportation (i.e., vehicles, trains, aerospace, and submarines) is not precisely defined, Derbyshire and Nottinghamshire have strong foundations to grow in all alternative propulsion technologies (i.e., electric, hydrogen, alternative fuels, nuclear). Establishing an organisation that could lead, coordinate, and coherently represent the cluster in its entirety along with the long-term, strong, and continuous commitment of the government are two of the most important areas of potential support for the growth of the cluster.

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Research note

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The Innovation Caucus supports sustainable innovation-led growth by promoting engagement between the social sciences and the innovation ecosystem. Our members are leading academics from across the social science community, who are engaged in different aspects of innovation research. We connect the social sciences, Innovate UK and the Economic and Social Research Council (ESRC), by providing research insights to inform policy and practice. Professor Tim Vorley is the Academic Lead. The initiative is funded and co-developed by the ESRC and Innovate UK, part of UK Research and Innovation (UKRI). The support of the funders is acknowledged. The views expressed in this piece are those of the authors and do not necessarily represent those of the funders.