European Commission

ESIR

Why Europe needs a systemic R&I policy

Redefining competitiveness for long-term sustainability

Policy Brief No. 6

Independent Expert Report

Research and Innovation

Why Europe needs a systemic R&I policy: Redefining competitiveness for long-term sustainability

ESIR Policy brief

European Commission
Directorate-General for Research and Innovation
Directorate G — Common Policy Centre
Unit G.1 — Common Strategy & Foresight Service
Contact César DRO
Email cesar.dro@*ec.europa.eu*
RTD-ESIR@*ec.europa.eu*
RTD-PUBLICATIONS@ec.europa.eu
European Commission
B-1049 Brussels

Manuscript completed in May 2024

1st edition

PDF	ISBN 978-92-68-17656-6	doi:10.2777/778358	KI-BE-24-002-EN-N

Luxembourg: Publications Office of the European Union, 2024

EUROPEAN COMMISSION

Why Europe needs a systemic R&I policy

Redefining competitiveness for long-term sustainability

A policy brief by the Expert Group on the Economic and Societal Impact of Research and Innovation (ESIR)

Katherine Richardson (ESIR Chair)
Andrea Renda (ESIR Vice-Chair)
Floor Alkemade (Rapporteur)
Rainer Walz
Jon Simonsson
Heather Grabbe
Paweł Świeboda
Pierre-Alexandre Balland
Kirsten Dunlop
Bianca Muntean
Epaminondas Christophilopoulos
Jean-François Huchet
Dunja Potočnik
Marzenna Weresa
Marialuisa Castaño Marin

2024 Directorate-General for Research and Innovation EN

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INTRODUCTION

The EU faces serious challenges regarding the competitiveness of its economy. Concerns span the entire innovation chain: In R&I the EU is lagging behind China and the US in key areas like digitization and AI. For areas where R&I performance is strong, this strength is not sufficiently translated into market and trade advantages. Moreover, while the number of start-ups is increasing somewhat, the EU is often not the preferred location for research-intensive scale-ups. As a result, there is a strong call to make European competitiveness a top policy priority. At the same time, climate change and the biodiversity crisis make it clear that the long-term competitiveness of any economy will be dependent on its ability to operate within the biophysical and resource limits of the Earth.

This report investigates how competitiveness can be defined in light of the current pressing global challenges, geopolitical tensions, attractiveness of the societal model and the existing capabilities of the EU's R&I system. It recognizes that a competitiveness strategy based on EU values looks different from the approaches used in the US and China. It also recognizes that policies targeting competitiveness, research & innovation, climate, welfare and economic security become increasingly intertwined, arguing for a systemic perspective on competitiveness.

Despite efforts to broaden indicators[1], existing approaches to competitiveness do not easily align with long-term well-being and societal robustness as they do not take into account the limited availability of natural, human and other resources and the key societal roles of attractive jobs, societal attractiveness and social cohesion. Moreover, measures focusing on creating competitive advantages have to consider the changes in the geopolitical landscape. It cannot be assumed that open markets will make the innovation success in a lead market available to all, which is necessary to tackle global challenges such as anthropogenic climate change. Moreover, strategies to enhance competitiveness typically focus on growth rather than on the robustness and distribution of that growth. Sustainable growth and an equitable distribution of the costs and benefits from the use of natural resources are key to realising long-term well-being and social cohesion. Increased social cohesion in itself has been identified as a key element of a competitive EU economy.

This report therefore proposes a systemic approach to competitiveness that recognizes planetary boundaries and internalises relevant costs. Specifically, we propose to define **a competitive EU economy as a fore-runner in maximising the societal value gained by using the Earth's limited natural resources while at the same time minimising the environmental and social costs**.[2]

This broad view of competitiveness has implications for the indicators used to monitor the competitiveness of the EU economy (and that may become policy goals in themselves) and the research and innovation policy that seeks to contribute to competitiveness. Below, we briefly discuss three perspectives on competitiveness that shape the current debate: First, the traditional perspective focused on increasing productivity, and second a first-mover

[1] European Commission, Directorate-General for Research and Innovation, Charveriat, C., Abdallah, S., Jong, S. et al., *New metrics for sustainable prosperity – Options for GDP+3 – A preliminary study*, Publications Office of the European Union, 2024, https://data.europa.eu/doi/10.2777/483660

[2] https://www.euractiv.com/section/economy-jobs/opinion/a-competitive-and-resilient-europe-requires-transitioning-from-sectoral-to-systemic-thinking/

advantage, which is often embedded into the perspective of fostering sustainable socio-technical systems. We then discuss how these perspectives may contribute to a systemic perspective (including mission-driven approaches). These three perspectives are not mutually exclusive but complement each other. Putting them together also enables us to derive important conclusions for priority setting of R&I policies. Policy domains that promise an increase in competitiveness from multiple perspectives are especially important.

To illustrate the interrelatedness of the three perspectives, we use two case studies: the transition to a circular economy and the build-up of a green hydrogen system. Both areas address the Earth's limited natural resources and the global climate challenge and, therefore, are aligned with the first element of our definition of long-term competitiveness. Indeed, increasing resource productivity is one of the key elements we put forward in developing a systemic perspective of competitiveness and furthermore underlines the importance of the case study on a circular economy. In the case studies, we examine more closely the relationship to the three competition perspectives introduced above. Specifically, we consider how Europe is positioned relative to its main competitors. e.g., USA, Japan and China, and how the two case studies support the case for a systemic perspective of competitiveness.

DIFFERENT APPROACHES TO FOSTERING COMPETITIVENESS VIA R&I POLICIES

In its broadest sense, competitiveness analyses, integrates and evaluates the totality of a nation's performance in a global environment[3]. Porter points to the relative nature of competitiveness and the role of pressure and challenges to explain the competitive advantages of an industry or business.[4] After the Lisbon goals with their emphasis on competitiveness and knowledge-intensive sectors, followed by a shift towards societal goals and emission reductions in the 2020 strategy and the green deal, competitiveness finds itself once again a policy focus but in a changed world.

The view of how exactly R&I policy should foster competitiveness has changed over time, co-evolving with the challenges the EU has been facing. In general, research and innovation policy is seen as key for contributing to future competitiveness by strengthening the knowledge base and building up capacities, ranging from policies focused on productivity to policies focused on creating lead markets and first-mover advantages by building socio-technical systems. Older policy instruments typically still persist and contribute to the policy mixes for newer approaches. For example, R&D subsidies have a role in all approaches. Hence, it is key to examine whether the different approaches are aligned and can be aligned with our broader definition of competitiveness. This section provides a brief outline of different approaches and evaluates their potential contribution to a systemic approach to competitiveness.

The traditional economic perspective: increasing productivity

The traditional economic approach of competitiveness focuses on productivity. Indeed, Krugman (1994)[5] in his seminal article stated that competitiveness is just another term for productivity. Factor endowment in terms of quantity, quality and price are key components of productivity, together with the efficiency with which these factors are combined and utilized. Thus, a nation or region can increase its competitiveness if it increases the quality, or lowers the price of its production factors, or if it moves towards improving coordination and usage of the factors.

A high labour productivity ensures a high economic output per hour worked. Typical indicators for measuring competitiveness are therefore the level and growth rates of labour productivity and GDP. In this line of thinking, competitiveness is linked to prosperity with regard to material well-being, with differences in the level of GDP sometimes even referred to as referred to as "prosperity gap"[6].

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[3] Garelli, S. (2018), 30 years of competitiveness research, available at https://www.imd.org/research-knowledge/competitiveness/articles/30-years-of-competitiveness-research/

[4] Porter, M. E. (1990), The Competitive Advantage of Nations, Harvard Business Review March/April 72-91.

[5] Krugman, P. (1994), Competitiveness: A Dangerous Obsession, Foreign Affairs,73(2), 28-44.

[6] McKinsey Global Institute (2024), Accelerating Europe's economic competitiveness, article from January 16, 2024, available at:

There is a long-standing debate about a persistent productivity gap between Europe and the U.S. Van Ark et al. (2008)[7] see such a transatlantic productivity gap since the mid-1990's being driven by lower advances in technology and innovation, among them lower contributions from investments in information and communication. Castellani et al. (2018)[8] summarize the debate about the transatlantic productivity gap and cluster it into three main drivers: first, different levels of investment in corporate R&D investments; second, structural differences between the economies, with R&D-intensive manufacturing and R&D-intensive service sectors being underrepresented in the European economy in comparison to the US; third, lower capacity of European companies for translating R&D investments into productivity gains.

There is mixed empirical evidence about the development of European competitiveness measured by productivity in recent years. Looking at the values per hour worked, OECD data shows that the EU27 trails the US with 56 $/h versus 74 $/h. The same data also show that both the EU 27 and the U.S. have achieved an almost identical albeit modest increase in the level of labour productivity between 2015 and 2022.[9] However, in addition to hourly labour productivity the attractiveness of Europe as a location for business is also influenced by the number of annual working days being lower than e.g., in the U.S.

The discussion about European competitiveness still emphasises the issues debated in the last 20 years. Thus, policies to increase R&D investments still play an important role. However, the focus is also shifting towards specific bottlenecks for future productivity[10].

- The digital transformation and the use of AI are seen as key enabling technologies, which will drive future productivity development. More specifically, the use of Artificial Intelligence in the economy, including in science (to accelerate scientific discovery and increase the productivity of science) is increasingly visible.[11]
- Shortages in skilled labour, which are projected to increase in the years ahead, will become an important bottleneck (even though recent studies of AI have shown its ability to increase productivity more of junior employees than of senior).
- The access to capital, both from private and public sources, has to increase to enable the required investment surge, e.g. for the build-up of new infrastructure. This involves, among others, the deepening of capital markets.

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https://www.mckinsey.com/mgi/our-research/accelerating-europe-competitiveness-for-a-new-era

[7] van Ark, Bart, Mary O'Mahoney, and Marcel P. Timmer (2008), The Productivity Gap between Europe and the United States: Trends and Causes." Journal of Economic Perspectives, 22 (1): 25-44

[8] Castellani, D.,Piva, M.,Schubert, T.,Vivarelli, M. (2018), Can European productivity make progress? Intereconomics 53(2), pp. 75-78

[9] According to OECD 2024, the labour productivity in 2022 was 6 % higher in 2022 than in 2015 in Europe, and 7 % higher in the U.S. https://data.oecd.org/lprdty/gdp-per-hour-worked.htm#indicator-chart

[10] See, for example the statements from Dusek, M., Gislen, M. (2024), How to increase Europe's competitiveness in the new global economy. Euractiv March 3, 2024, available at: https://www.euractiv.com/section/economy-jobs/opinion/how-to-increase-europes-competitiveness-in-the-new-global-economy/; McKinsey 2024, op.cit.; Tagliapietra, S., Veugelers, R., Zettelmeyer,j. (2024), Guiding the EU's quest for economic competitiveness, Politico February 14, 2024, available at: https://www.politico.eu/article/guiding-the-eus-quest-for-economic-competitiveness/

[11] https://www.pwc.com/gx/en/issues/artificial-intelligence/job-barometer/report.pdf

- Further integration of the single market is needed to facilitate economies of scale and reduce fragmentation in order to allow EU companies to scale up within the single market.[12]

- Adequate governance and regulation of technology are seen as key factors for enabling and accelerating responsible innovation uptake and ensuring Europe's values simultaneously.[13]

The multitude of these factors shows in that increasingly composite indicators such as the European Innovation Scoreboard are used to measure the ability for future increases in productivity. The results for Europe confirm a gap towards leading countries such as South Korea and the US. The EU is still slightly ahead of Japan and China, with the latter catching up quickly. These results point toward the need that Europe has to accelerate its performance.

Addressing these issues requires a more systemic policy approach, with policies becoming more and more horizontal, encompassing not only traditional R&I policies but industrial, monetary, public sector and competition policies as well. This urgent need for well-designed R&I policies embedded in the overall policy design is also one of the main messages of the Commission's R&I policy paper on why R&I investments matter for a competitive, green, and fair Europe, exploring additional pathways to strengthen public and private efforts to reap the full potential of R&I.[14] However, given our definition of long-term competitiveness in the introduction, such a systemic policy approach is not sufficient, and has to be complemented in three key dimensions of sustainable competitiveness: social, environmental and institutional prosperity - an issue we will turn to below.

The socio-technical perspective: first mover and lead market for more sustainable socio-technical systems

The socio-technical perspectives on competitiveness focuses on the role of first-mover effects and lead markets for transitioning socio-technical systems to a more sustainable trajectory[15]. This perspective combines the economic rationale to achieve success in trade in knowledge intensive technologies with forging ahead with the development of more sustainable socio-technical systems. Strategically, this perspective offers a view that economic success and prosperity related to the successful build-up of sustainable socio-technical systems are complementary and not contradictory.

[12] Expert group on the Economic and Societal Impact of R&I (ESIR), Combining Regional Strengths to Narrow the Innovation Divide, upcoming 2024.

[13] Expert group on the Economic and Societal Impact of R&I (ESIR), Technology Governance for sustainable development, upcoming 2024.

[14] European Commission, Directorate-General for Research and Innovation, Steeman, J., Di Girolamo, V., Mitra, A. et al., *Why investing in research and innovation matters for a competitive, green, and fair Europe – A rationale for public and private action*, Publications Office of the European Union, 2024, **https://data.europa.eu/doi/10.2777/01237**

[15] A socio-technical system is defined as a configuration of technologies, regulations and actors, services and infrastructure that fulfils a societal function (e.g. energy provision).

The economic rationale of this perspective is based on two explanatory approaches that point to the importance of innovation for achieving economic success: Firstly, evolutionary economics emphasises that foreign trade successes in technology-intensive goods are partly caused by technological capabilities. Under these conditions, cost disadvantages in labour costs play a smaller role and innovation capability matters.[16] Secondly, the concept of the first-mover advantage - also known as the Porter hypothesis - explains how a national leadership role in the environmental sector can also lead to economic success. Here a forced national strategy that develops the domestic market into a global lead market leads to specialisation in the provision of the necessary goods at an early stage. If international demand for these goods subsequently expands, the fore-runner countries are then able to become the leading suppliers due to their early specialisation and the innovation edge they have achieved.[17]

With increasing globalisation some emerging economies have also gained a foothold in more technology-intensive markets, and lead market effects are increasingly also discussed from the perspective of the global South.[18] Furthermore, a demand-side innovation policy such as an ambitious environmental policy alone is not enough to achieve the desired first-mover advantage. Rather a more systemic approach is needed. This is illustrated by the example of how China devised a specific industrial policy, including strategic R&I, to gain a first-mover advantage in electric vehicles.

More specifically, the countries that are most likely to become or remain significant leading suppliers on the global markets in the long term are those that have built up a capable and differentiated innovation system adapted to the needs of the global market, *and* that have competitive suppliers with the relevant experience. This is equivalent to the conditions for building strong innovation ecosystems, which drive forward sustainable socioeconomic systems. Thus, the success factors for economic success in trade, and for the successful build-up of sustainable socio-technical systems reassemble each other.[19]

The following factors, which encompass supply and demand-side conditions, have emerged as relevant for assessing a country's prospects of forming a lead market and becoming a lead supplier from a systems perspective[20]:

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[16] Dosi, G., Soete, L. (1988), Technical change and international trade, in: Dosi, G. et al. (eds.): Technical Change and Economic Theory, Pinter, London. Fagerberg. J. (1988), International Competitiveness. The Economic Journal, 98 (June), 355-374. Amable, B., Verspagen, B. (1995), The role of technology in market shares dynamics. Applied Economics (27), 197-204. Wakelin, K. (1998), The role of innovation in bilateral OECD trade performance. Applied Economics (30), 1335-1346.

[17] Porter, M., and C. van der Linde (1995), Toward a New Conception of the Environment-Competitiveness Relationship, Journal of Economic Perspective 9(4), 97–118. Ambec, S., Cohen, M.A., Elgie, S., Lanoie, P. (2013), The Porter Hypothesis at 20: Can Environmental Regulation Enhance Innovation and Competitiveness? Review of Environmental Economics and Policy 7(1), 2-22

[18] Walz, R.; Pfaff, M.; Marscheider-Weidemann, F.; Glöser-Chahoud, S. (2017): Innovations for reaching the green sustainable development goals – where will they come from? International Economics and Economic Policy 14 (3) 684-695. Herman, K.S. (2023), Green growth and innovation in the Global South: a systematic literature review, Innovation and Development 13 (1), 43-69.

[19] Walz, R., Köhler, J. (2014), Using lead market factors to assess the potential for a sustainability transition. Environmental Innovation and Societal Transitions 10, 20-41.

[20] Beise, M. (2004), Lead markets: country specific drivers of the global diffusion of innovations. Research Policy 33, 997-1028.; Quitzow, R., Walz, R., Köhler, J., Rennings, K. (2014): The concept of "lead markets" revisited: Contribution to environmental innovation theory. Environmental Innovation and Societal Transitions 104-19; Walz and Köhler 2014, op. cit.

- Successful foreign trade in technology-intensive goods still requires a high level of technological and industrial performance. Among the various indicators that measure technological performance, transnational patents in particular have been shown to be an important variable in econometric analysis in explaining export performance.

- The market context factors on the demand side encompass the factor's demand advantage and price advantage. A demand advantage exists when consumers, entrepreneurs or businesses within a country anticipate global trends and future technology requirements earlier than other countries, as China successfully did with green tech[21]. Strong domestic market growth indicates that there may be both scale-related price advantages and a particularly large number of opportunities for gaining user experience and interaction between users and manufacturers of technologies.

- Success factors on the supply side relate to the exporter's expertise in international marketing and their knowledge of foreign markets These factors are more likely to occur when exports are high and distributed across the individual export markets, meeting different demand conditions.

- Improving one's own position in quality competition also depends on the actor and system structure. This involves the size of the individual players and the formation of networks between companies, science, manufacturers, regulators and users of the technologies but also the ability to combine technical developments, new business models and service concepts.

- Innovations are influenced by regulation in a variety of ways. A country with a progressive regulatory system that is adopted by other countries has advantages. It is important that the players consider the regulation to be stable and predictable on the one hand, but also relevant for innovations occurring in times of rapid change and new technologies on the other hand. At the same time, regulation has the function of specifying ambitious medium-term goals that help to guide the direction of innovation.

The concepts of lead market and first-mover advantages have influenced past and current EU policies. Already in 2008, the EU started with the Lead Market Initiative, which aimed at fostering the development of the EU in six areas of sociotechnical systems.[22] More recently, the economic rationale of the Green Deal is linked to the concept of first-mover advantages and lead markets for sustainable socio-technical systems. Climate technologies (e.g. for renewable or rational use of energy) and other environmental technologies belong to the technological domains in which Europe has shown a particular strength over time. Even though the share of climate and environmental patents has been decreasing over time – with China increasing its share to 16% and 17 % respectively - the EU 27 has constantly achieved a positive revealed patent advantage (RPA) in these domains (Figure 1). This indicates that these technologies belong to the domains in which the EU has been specializing, and the

[21] https://www.bruegel.org/policy-brief/de-risking-and-decarbonising-green-tech-partnership-reduce-reliance-china

[22] Commission of the European Communities (2007), A lead market initiative for Europe, COM(2007) 860 final. Georghiou, L. Georghiou, L. (2011). Final Evaluation of the Lead Market Initiative. Publications Office of the European Union. https://doi.org/10.2769/29882

increasing specialization since 2010 forms an important argument for both the success of past policies and strategic choice to make these domains also the basis for increasing European competitiveness in the future[23]. However, as pointed out, the conditions for establishing lead markets and first-mover advantages go far beyond technological performance. For example, on measures beyond patents such as trade, China has been far more successful than in patenting.[24] In this context, over-capacities and dumping complicate reaping the benefits of first-mover advantages in many high-tech areas,[25] call for a more systemic approach which involves policy domains beyond R&D policies.

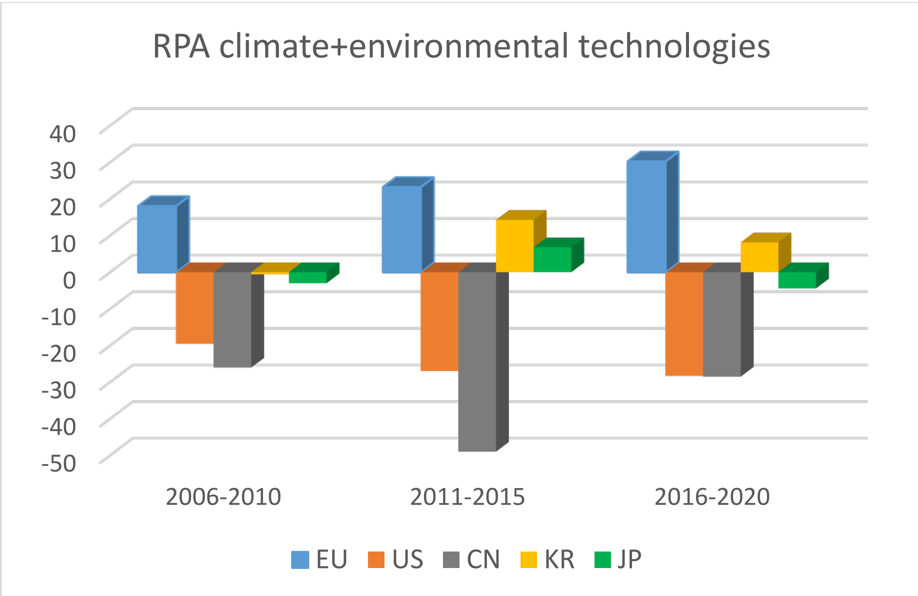

FIGURE 1 - DEVELOPMENT OF RPA OF EU 27 AND SELECTED COUNTRIES IN CLIMATE AND ENVIRONMENTAL TECHNOLOGIES. SOURCE: AUTHOR'S OWN COMPILATION USING CALCULATIONS FROM FRAUNHOFER ISI BASED ON PATSTAT DATA

From a systemic perspective, continuing support for R&D in these domains must be broadened and should also encompass not only technological, but also organisational, social, and institutional innovations. The integration of these R&I policies with other sectoral policies to align demand is key. It is necessary to channel investments towards these domains, and to come up with ambitious climate and environmental policies also in the years ahead. This also involves phasing out unsustainable technologies and sectors and giving price signals which incentivize these changes. The role of the public sector is crucial: Many examples show that public actors have played a decisive role in innovation processes.

[23] Li, D., Alkemade, F., Frenken, K., & Heimeriks, G. (2023). Catching up in clean energy technologies: a patent analysis. *The Journal of Technology Transfer*, *48*(2), 693-715.
[24] Garcia-Herrero, A., Grabbe, H., Källenius, A. (2023), De-risking and decarbonising: a green tech partnership to reduce reliance on China, available at https://www.bruegel.org/policy-brief/de-risking-and-decarbonising-green-tech-partnership-reduce-reliance-china; Walz et al. (2017), op. cit.
[25] Boullenois, C., Kratz, A., Rosen, D.H. (2024), Overcapacity at the Gate, available at https://rhg.com/research/overcapacity-at-the-gate/

Ericsson's successes for example are largely based on the company's long and intimate collaboration with its large state customer Televerket. They became a "development pair" that was behind among others the GSM mobile system.

Here we see a potential trade-off between short-run and long-term competitiveness. Lower prices for fossil fuel-based energy in Europe, for example, might increase the price competitiveness of energy-intensive industries relying on fossil fuel in the short run but would reduce the incentive to move towards energy efficiency and renewable energies. This would lower the market factors on the demand side for the related technology domains. Thus, ESIR emphasises that lowering energy costs, as envisaged by European leaders in their April 2024 statement[26], has to be interpreted as building new capacities of renewable energy sources, which leads to cost reductions, and push for energy efficiency technologies which reduce energy demand. Slowing down progress in these areas would not increase but decrease European competitiveness in technology-intensive export markets, which is why subsidies for imported fossil fuels to reduce energy costs short-term would not be the right approach, as long-term European competitiveness would be served by incentives to switch to renewables.

Building blocks of a more systemic approach

The traditional competitiveness approaches and indicators described above are not fully aligned with the broader definition of competitiveness introduced above. Below we identify implications for R&I policy. The first building block of a systemic approach to R&I policy that maximizes sustainability and well-being is to adopt resource and material productivity as key targets for R&I policy. This systemic and more holistic approach to competitiveness echoes the earlier work of the European Commission and ESIR on the Industry 5.0 concept.[27],[28] The core argument here is that industrial innovation must address sustainability, human-centricity and resilience aspects, going beyond narrowly constructed productivity, for industry in Europe to remain competitive. The EU's relative resource scarcity may support a first-mover effect driven by R&I policies and stringent regulation to develop innovation in resource-efficient products and services.

The second building block is social attractiveness. In a broad view of competitiveness, the EU needs to be truly attractive for skilled labour and capital, but also in general as a society and a place to live and work. Traditional labour productivity statistics do not capture the multiple roles that labour, specifically attracting cutting-edge knowledge workers and entrepreneurs, plays in a competitive economy. Specifically the attractiveness to scarce labour and cutting-edge knowledge in AI, biotech and green tech is key. Regarding capital, current key questions concern the availability and risk-reward profile of capital rather than its productivity. These issues are also core to a competitiveness view based on comparative

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[26] EU Directorate-General for communication (2024), EU leaders call for strengthening the EU's competitiveness, News article available at:
https://commission.europa.eu/news/eu-leaders-call-strengthening-eus-competitiveness-2024-04-19_en

[27] European Commission, Directorate-General for Research and Innovation, Steeman, J., Di Girolamo, V., Mitra, A. et al., *Why investing in research and innovation matters for a competitive, green, and fair Europe – A rationale for public and private action*, Publications Office of the European Union, 2024, **https://data.europa.eu/doi/10.2777/01237**

[28] European Commission, Directorate-General for Research and Innovation, Renda, A., Schwaag Serger, S., Tataj, D. et al., *Industry 5.0, a transformative vision for Europe – Governing systemic transformations towards a sustainable industry*, Publications Office of the European Union, 2021, **https://data.europa.eu/doi/10.2777/17322**

advantage for the EU. Moreover, the EU's comparative advantage can also arise from its attractiveness as a place to live and work.

In a systemic approach, these building blocks would be embedded in and fully aligned in a horizontal policy mix to ensure that R&I is translated to competitive advantage and increased well-being and sustainability.

Resource and material productivity as key targets for innovation policy

Global material productivity improvements lag behind growth rates of labour, energy and greenhouse gas (GHG) productivity and have stagnated since 2012[29]. Innovation policies should target improved resource productivity and sustainable production and consumption systems that efficiently deliver essential services—such as built environment, mobility, food, and energy — with significantly reduced material and energy inputs and diminished emissions as part of a broader systemic policy mix. UNEP (2024) shows how resource efficiency efforts are aligned with reducing GHG emissions and increasing well-being, where well-being is measured using the inequality-adjusted Human Development Index (IHDI) and its three components (gross national income per capita, education and life expectancy).

Specific innovation targets include resource efficiency innovation, incentives and support for technology demonstration and deployment. To avoid rebound effects, UNEP (2024) advises coupling such policies with policies that encourage more efficient use of resources, such as more stringent environmental standards or a levy on virgin resources (where the income from the levy could be used to support innovation further). Innovation policy support for resource recovery and recycling is a crucial element of such a policy package, especially given the relative resource scarcity in the EU.

Beyond technological innovation, a resource-efficient economy requires innovation in circular, resource-efficient and low-impact business models, as well as complementary social and deployment-oriented activities to ensure implementation at speed and scale. It is also required to develop governance and permitting regimes, functioning across sectors, that are adaptive and conducive to new technologies and innovative solutions e.g. to enable usage of rest-flows such as using industries' warm-waste-water streams for agriculture. Supportive regulation, for example, through eco-design standards, ambitious resource productivity targets or extended producer responsibility (EPR), accelerates these innovation efforts. Such efforts may even lead to first-mover advantages for EU firms, an issue we will look at in the case study on the circular economy below.

However, from a systemic perspective, it is key that environmental burdens are not displaced to other countries. Reasoning from a broad view on competitiveness, any comparative advantage for the EU needs to be embedded in trade relations that also allow EU trade partners to further develop towards their sustainable development goals.[30] Our broad

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[29] United Nations Environment Programme (2024): Global Resources Outlook 2024: Bend the Trend – Pathways to a liveable planet as resource use spikes. International Resource Panel. Nairobi. https://wedocs.unep.org/20.500.11822/44901

[30] Caiafa, C., Hattori, T., Nam, H., & de Coninck, H. C. (2023). International technology innovation to accelerate energy transitions: The case of the international energy agency technology collaboration

definition of competitiveness explicitly takes a global perspective. ESIR has already pointed out that global trade relations can be a cause of increasing risk but also an opportunity to realize economies of scale and to foster new forms of collaboration, e.g. with countries of the Global South[31]. A competitive Europe can only thrive if its trade partners also benefit and can meet their own transition goals. This requires effective and responsible technology transfer strategies. Technology transfer and international collaboration would be needed for the research and the global scaling up of low-carbon materials. However, such strategies must also address, in some sense, more short-term aspects of security and the ability to defend and align with EU values.

A competitive EU economy must be socially attractive

Attractiveness is a crucial long-term factor in the global scramble for talented people, investments, and know-how. It is a prerequisite for competitiveness. The European House – Ambrosetti has developed the Global Attractiveness Index (GAI) to provide countries with a tool to measure and benchmark a country's attractiveness as a determining element of its ability to be competitive and grow.[32,33] The GAI –builds on four attributes of attractiveness - Openness, Innovation, Efficiency, and Endowment - which are captured by 21 Key Performance Indicators[34], then aggregated into a single summary measure of attractiveness. Important aspects of the European Union's attractiveness are the high level of well-being, the provision of key services, and the relatively low level of inequality.

Societal attractiveness is key to attracting skilled labour to the EU. A challenge is to attract labour in a way that supports social cohesion. Here, local content policies and policies that seek to enhance local value retention, both within the EU and globally are important to ensure that circular innovation and business models support social cohesion. Attention should also be given to how specific innovation trajectories include the quality and location of jobs provided as well as the skills required (SSH agenda). A focus on human-friendly technologies[35], i.e., technologies that work with humans or greatly contribute to their well-being could also help. Locally embedded innovation strategies building on local capacities, can strengthen social cohesion and resilience. Specifically, digital innovations can support the right to stay, strengthening social cohesion. Despite such efforts, the process of

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programmes . *Environmental Innovation and Societal Transitions*, *48*, Artikel 100766. https://doi.org/10.1016/j.eist.2023.100766

[31] European Commission, Directorate-General for Research and Innovation, Dixson-Declève, S., Renda, A., Schwaag Serger, S. et al., *Research, innovation, and technology policy in times of geopolitical competition*, Publications Office of the European Union, 2023, **https://data.europa.eu/doi/10.2777/745596**

[32] Saisana, M., Montalto, V., Caperna, G., Damioli, G., Dominguez Torreiro, M., Neves, A.R. and Tacao Moura, C.J., JRC Statistical Audit of the 2021 Global Attractiveness Index, EUR 30897 EN, Publications Office of the European Union, Luxembourg, 2021, ISBN 978-92-76-43804-5, doi:10.2760/006415, JRC127156.

[33] Lee, K.-H. (2016). The conceptualization of country attractiveness: a review of research. International Review of Administrative Sciences, 82(4), 807-826. https://doi.org/10.1177/0020852314566002

[34] including non-financial issues like CO2 emissions

[35] Johnson, S., & Acemoglu, D. (2023). *Power and progress: Our thousand-year struggle over technology and prosperity*. Hachette UK.

innovation has a tendency to create inequalities and it is key that the proceeds of innovation should benefit all to maintain long-term robust and attractive societies[36],[37].

A competitive EU economy must use a systemic approach to R&I policy

The challenges faced by Europe can only be addressed through initiatives that respect interactions within socio-economic systems. Such an approach requires, among other things, cross-sector innovation and further integration of energy and financial markets[5]. UNEP (2024) illustrates how such an integrated approach could lead to increased well-being at little environmental cost, decoupling human well-being from resource use and environmental impacts.

The green and digital transition is key to the EU's efforts to remain competitive in the longer term. In this context, the EU has accelerated its transition towards climate neutrality and digital leadership. Regarding digital leadership, there is a clear challenge to catch up, especially when building strong capacities in these technologies is considered of strategic importance.

The envisioned economic benefits the green transition would bring to Europe were based on the assumption of free trade: The necessary inputs for green technologies were thought to be unrestricted. The opportunity to reap the benefits of obtaining a first-mover advantage by selling the technologies to the world and making them available to all was not expected to be restricted by protectionist trade policies. But today, innovation challenges are found in innovating around security of supply concerns and increased competition from strong industrial policies in China and the US. This calls for a more systemic policy, which links domestic R&I policies and domestic industrial policies much more with trade and foreign policy. The relative resource scarcity and the expected relatively higher energy prices in the EU provide a further incentive to develop a resource-efficient economy. At the same time, for EU climate strategies to be successful, the benefits of EU green and digital innovation need not only to be sustainably distributed within the EU but also globally balanced.

One of the key interactions that should be fostered where possible is that between digital innovation and innovation in people-friendly technology as a stimulus for the creation of good, local jobs. This, in turn, contributes to social cohesion and competitiveness as some of the integration measures (infrastructure, capital markets, energy systems) needed for competitiveness critically depend on social cohesion and broad societal support.

In the longer term, the challenge remains to foster the innovation capacity that leads to dynamic competitiveness, as building competitiveness in certain technologies will be an important source for future competitiveness. This includes directing innovation efforts towards alternatives for critical materials and technologies for which the security of supply is a concern. It also includes high-risk innovation activities in new directions[38] Here, the

[36] See ESIR policy brief on the innovation divide (Upcoming 2024)

[37] Philippe Aghion, Ufuk Akcigit, Antonin Bergeaud, Richard Blundell, David Hemous, Innovation and Top Income Inequality, *The Review of Economic Studies*, Volume 86, Issue 1, January 2019, Pages 1–45, https://doi.org/10.1093/restud/rdy027

[38] Fuest, C, D Gros, P-L Mengel, G Presidente and J **Tirole** (2024), "EU Innovation Policy: **How to Escape the Middle Technology Trap**"

structure and complexity of the EU knowledge base as a source of future innovation need to be investigated.

The EU has identified several key areas and accompanying indicators to measure progress on long-term competitiveness[39]. These areas are a functioning single market, access to private capital and investment, public investment and infrastructure, research and innovation, energy and circularity. These areas are not independent. However, current indicators and policy initiatives targeting these indicators do not sufficiently recognize these interdependencies.

[39] COM(2023) 168 final COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE COUNCIL, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE AND THE COMMITTEE OF THE REGIONS Long-term competitiveness of the EU: looking beyond 2030

THE CIRCULAR ECONOMY[40]

In contrast to the current "linear" economic model, the circular economy is an economic paradigm where input products are reused and waste is greatly reduced within the socioeconomic system.[41] Its main principles include reducing initial resource use, increasing the durability of products, increasing use rates through circular business models, and increasing the efficiency from which used resources are turned into new products.[42,43,44] Frameworks such as "reduce-reuse-recycle" or "narrow-slow-close" encapsulate the concept.

Applying circular economy principles to four key sectors (cement, steel, plastic and aluminium production) could reduce emissions by 40% by 2050.[45] Circular economy interventions, through the reduction of new land-use change and release of pollutants, could halt biodiversity loss, and help it recover to the levels it was at in 2000 by 2035 (Forslund et al., 2022).[46]

The circular economy and productivity growth

In his recent report, Enrico Letta outlines different ways in which a Circular Single Market could benefit European competitiveness[47]. The first is by eliminating inefficiencies in production that are currently hidden because resource prices are too low because the costs of their environmental impacts are not captured. By increasing efficiency in how goods are produced and in how long they are used, the EU can achieve greater productivity that can enhance its competitiveness in the long term. The European continent is poor in fossil energy but rich in human capital, and a front-runner in creating regulations that create and lead markets. The right-to-repair regulation is an example here. EU's comparative advantage could lie in developing the most energy and resource-efficient products and services. That could also benefit the regions where they are made, by reducing the local impact on freshwater and avoiding pollution where raw materials are sourced.

[40] Part of the analysis is developed in Heather Grabbe and Luca Léry Moffat (2024, forthcoming), "A Circular Single Market for Economic Security and Competitiveness", Policy Brief, Brussels: Bruegel.
[41] Kovacic, Z., R. Strand, and T. Völker (2020) *The Circular Economy in Europe: Critical Perspectives on Policies and Imaginaries* (Abingdon, Oxon ; New York, NY: Routledge)
[42] Bocken, N. M. P., I. De Pauw, C. Bakker, and B. Van Der Grinten (2016) 'Product design and business model strategies for a circular economy', *Journal of Industrial and Production Engineering*, 33:5, 308–20, available at https://doi.org/10.1080/21681015.2016.1172124
[43] Geissdoerfer, M., S. N. Morioka, M. M. De Carvalho, and S. Evans (2018) 'Business models and supply chains for the circular economy', *Journal of Cleaner Production*, 190, 712–21, available at https://doi.org/10.1016/j.jclepro.2018.04.159
[44] Allwood, J. M. (2014) 'Squaring the Circular Economy', in *Handbook of Recycling* (Elsevier), pp. 445–77, available at https://doi.org/10.1016/B978-0-12-396459-5.00030-1
[45] Ellen Macarthur Foundation (2019) *Completing the Picture: How the Circular Economy Tackles Climate Change*
[46] Forslund, T., A. Gorst, C. Briggs, D. Azevedo, and R. Smale (2022) *Tackling Root Causes: Halting Biodiversity Loss through the Circular Economy* (Sitra studies 205)
[47] Letta, E. (2024). Much More Than a Market-Speed, Security, Solidarity: Empowering the Single Market to deliver a sustainable future and prosperity for all EU Citizens.

The price of raw materials has indeed been artificially low as it has not to any larger extent included the environmental impact of their extraction. Price increases are now anticipated owing to water stress and other climate impacts, as well as more governments starting to price pollution and emissions. Therefore, European companies gain a future advantage if they already make their production processes more efficient in the use of materials.

A circular economy perspective calls for adapting the typical productivity-oriented perspective of competitiveness presented above. The traditional perspective measures competitiveness with regard to the development of, in particular, labour productivity. It is now also increasingly necessary to consider the development of resource productivity as another important indicator of competitiveness.[48] Within their green indicators system, the EU and also the OECD have established data series for resource productivity measuring the output of $ in GDP per kg of domestic material consumption (DMC). Figure 2 shows that productivity has been increasing for all major economies. The resource productivity of the EU 27 is somewhat higher than in the U.S, trailing Japan, but clearly higher than in China. The increase in material productivity, however, has been lower than for labour productivity (Figure 3). The development of the DMC in tonnes indicates that the EU, Japan and the U.S. indeed have succeeded in an absolute decoupling of GDP growth and domestic material consumption, while this is not the case for China (Figure 4). This development does not, however, only reflect success in circular economy strategies, but also results from structural changes in the economy, e.g., changes towards a more service-oriented economy or in the worldwide division of labour.

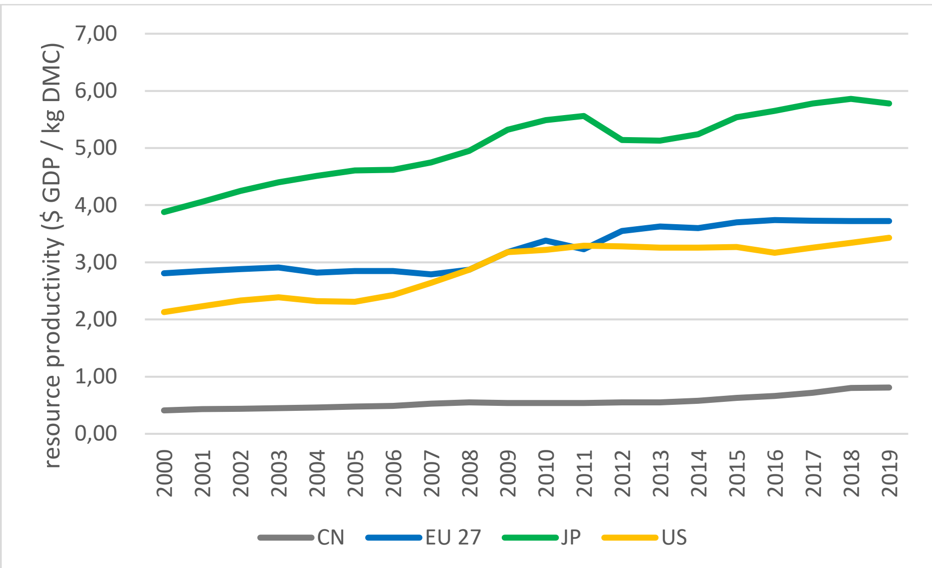

FIGURE 2 - DEVELOPMENT OF RESOURCE PRODUCTIVITY. SOURCE: AUTHOR'S OWN COMPILATION, BASED ON OECD GREEN GROWTH INDICATOR DATA

[48] M.E. Porter, C. van der Linde, Green and Competitive. In : M.E. Porter On Competition. The Harvard Business Review 2008, p. 348

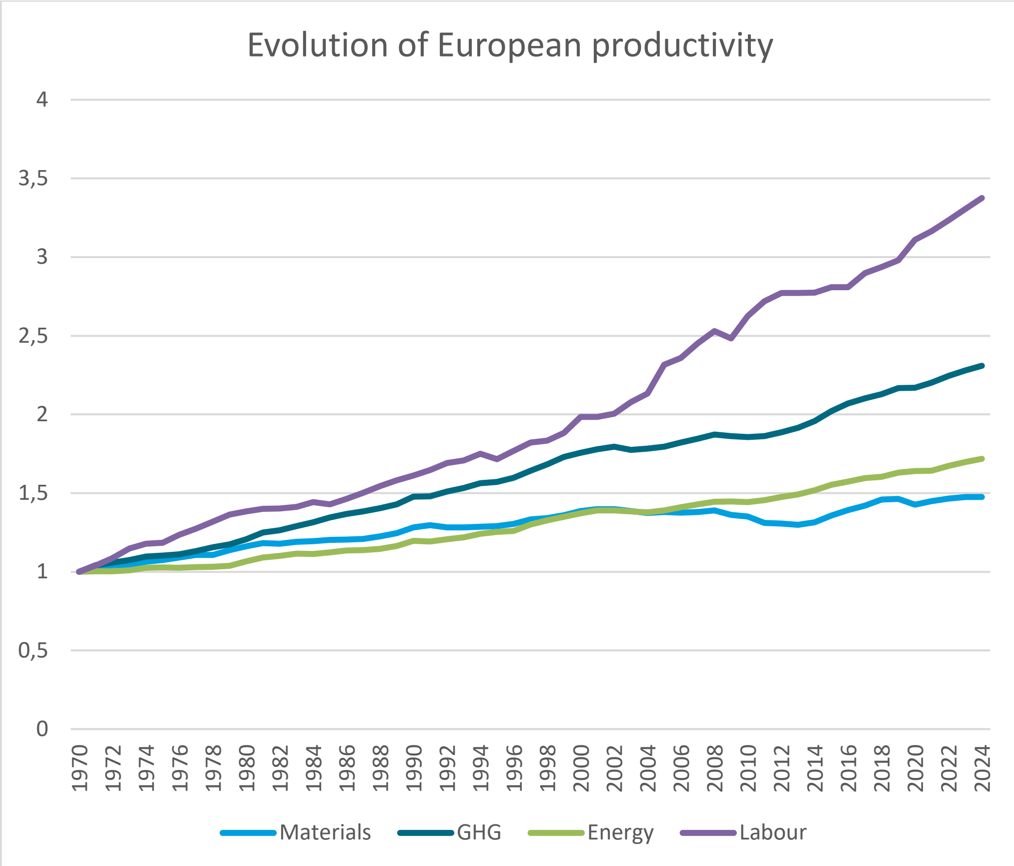

FIGURE 3 - EVOLUTION OF EUROPEAN PRODUCTIVITY. SOURCE: UN ENVIRONMENT PROGRAMME (2024) 'GLOBAL RESOURCES OUTLOOK 2024[49]

[49] United Nations Environment Programme (2024): Global Resources Outlook 2024: Bend the Trend – Pathways to a liveable planet as resource use spikes. International Resource Panel. Nairobi. https://wedocs.unep.org/20.500.11822/44901

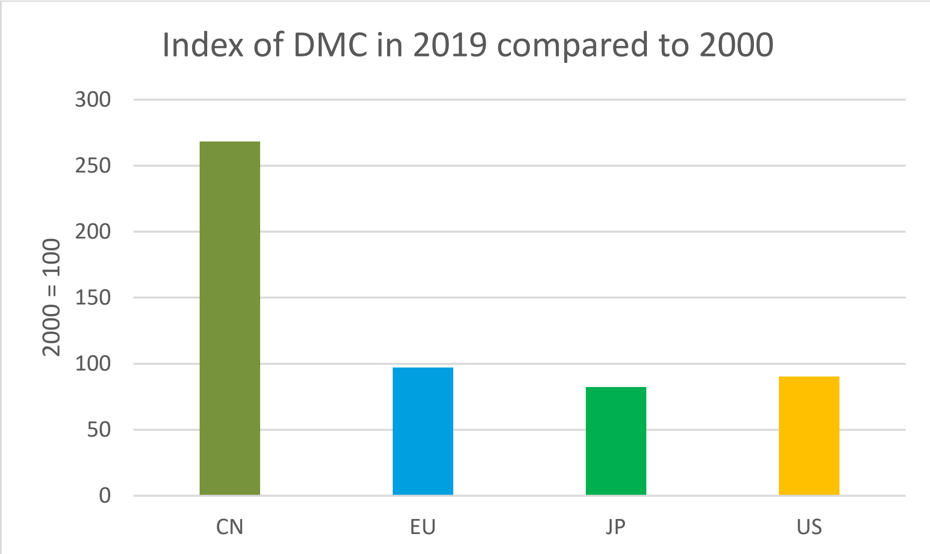

FIGURE 4 - DOMESTIC MATERIAL CONSUMPTION (DMC). SOURCE: AUTHOR'S OWN COMPILATION, BASED ON OECD GREEN GROWTH INDICATOR DATA

First-mover advantages and lead markets for circular economy systems

The second perspective of competitiveness deals with the prospect of achieving first-mover advantages in exporting technologies. This is a second reason to push the circular economy. Europe will lose further competitiveness if we miss the growth of new, green sectors. This also holds for products and services around the circular economy[50]. The EU can become a world leader in developing such markets, attracting investments and expertise. For instance, the European remanufacturing market's circular potential is projected to grow from its current value of €31 billion to €100 billion by 2030, creating half a million new jobs.[51,52] In Finland, the circular potential for textile fibres is estimated to yield €1.2 billion in investments and generate 17,000 new jobs. [53]

[50] EEA (2024) *Accelerating the Circular Economy in Europe: State and Outlook 2024* (European Environment Agency)
[51] World Bank (2022) *Squaring the Circle: Policies from Europe's Circular Economy Transition* (World Bank)
[52] European Commission, Directorate-General for Research and Innovation, Dixson-Declève, S., Dunlop, K., Renda, A. et al., *Industry 5.0 and the future of work – Making Europe the centre of gravity for future good-quality jobs*, Publications Office of the European Union, 2023, https://data.europa.eu/doi/10.2777/685878

[53] VTT (2021) 'The Finnish textile industry will be the most responsible and functional in the world in 2035 – investment opportunities of more than billion euros', available at https://www.vttresearch.com/en/news-and-ideas/finnish-textile-industry-will-be-most-responsible-and-functional-world-2035 [accessed 4 April 2024]

A crucial part of building a functioning circular economy is well-functioning markets for secondary raw materials characterised by the right price signals and standardised product-quality specifications.[54] In the last two years, various important packages of measures proposed in the Circular Economy Plan from 2020 have been taken:

- The Sustainable Products Initiative, including the proposal for the Ecodesign for Sustainable Products Regulation
- The EU strategy for sustainable and circular textiles
- Proposal for a revised Construction Products Regulation
- Proposal for empowering consumers in the green transition
- Revision of the EU rules on Packaging and Packaging Waste
- Communication on a policy framework for biobased, biodegradable and compostable plastics
- Proposal on common rules promoting the repair of goods.

All these packages aim to contribute to the growth of the domestic market and thus improve the market factors on the demand side.

As pointed out in section 1.2, especially transnational patents have been shown to be an important variable for measuring technological capabilities relevant to export performance. Not all of the circular economy approaches are captured by classifications that can be used for patent analysis. One approach has been to use the EEA classification scheme of the Environmental Protection Activities (CEPA) and Resource Management Activities (CReMA) as a starting point, and to develop a patent search strategy for circular economy technologies which includes CEPA 3 (Waste Management including general recycling technologies) and CReMA 13 c and 14 (specific recycling technologies).[55] Among these circular economy technologies, Europe has shown a particular strength over time. Even though the share of climate and environmental patents has been decreasing over time – with China increasing its share to 18 % for general waste and recycling technologies and 13 % for specific recycling technologies respectively - the EU 27 has constantly achieved a positive revealed patent advantage (RPA) in these domains (Figure 5 a and b). This indicates that these technologies belong to the domains in which the EU has been specialising. In contrast, both China and the U.S. show a negative specialisation. Europe's specialisation in both domains has been increasing since the early 2000s up to about 2010 but has remained fairly constant since then.

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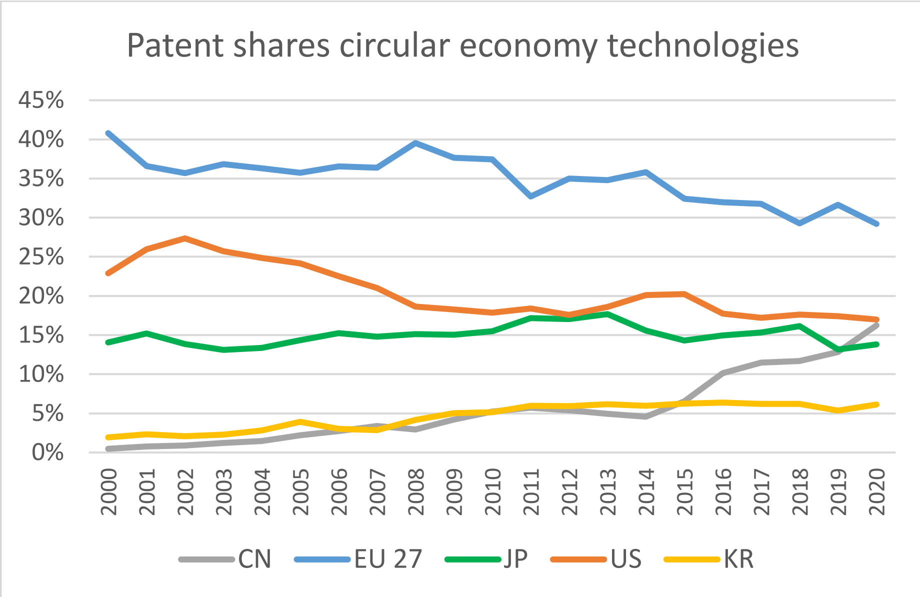
[54] EEA (2024), op. cit.

[55] Eurostat 2020, Classification of Environmental Protection Activities and Expenditure (CEPA) and Classification of Resource Management Activities (CReMA) explanatory notes, available at https://ec.europa.eu/eurostat/documents/1798247/12177560/CEPA+and+CReMA+explanatory+notes+-+technical+note.pdf/b3517fb9-1cb3-7cd9-85bd-4e3a3807e28a?t=1609863934103 ; Ingwersen, K., Gulden, S., Gehrke, S., Schasse, U. Ostertag, K., Marscheider-Weidemann, F., Rothengatter, O., Stijepic, D. , Innovationsmotor Umweltschutz: Forschung und Patente in Deutschland und im internationalen Vergleich, Report of German Federal Environmental Agency , available at https://www.umweltbundesamt.de/sites/default/files/medien/11850/publikationen/02_2024_uib_innovationsmotor.pdf



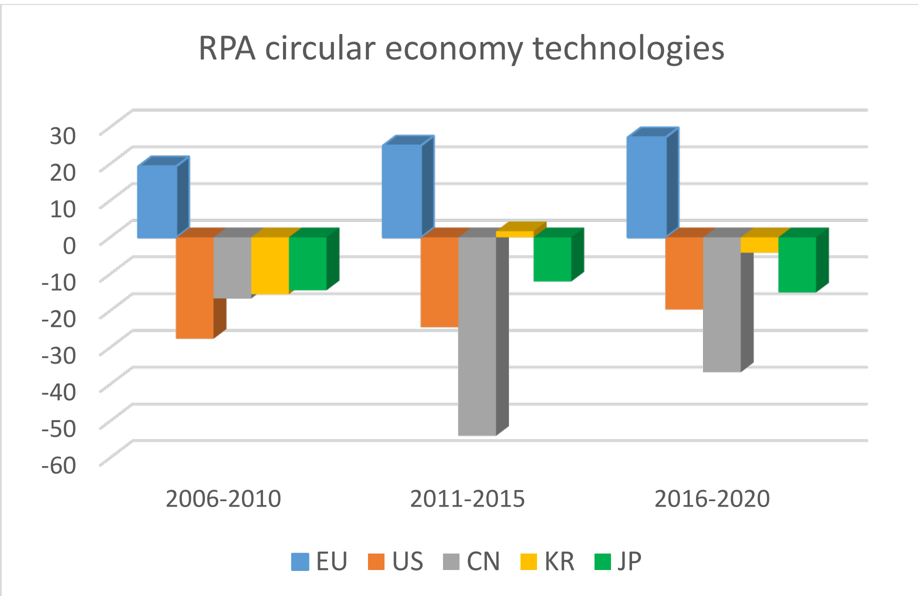


FIGURE 5 A AND B - DEVELOPMENT OF PATENT SHARES (5A TOP) AND RPA (5B BOTTOM) OF SELECTED COUNTRIES IN CIRCULAR ECONOMY TECHNOLOGIES. SOURCE: AUTHOR'S OWN COMPILATION, USING CALCULATIONS FROM FRAUNHOFER ISI BASED ON PATSTAT DATA

The market supply factors and the actor and systems structure in Europe are also favourable for the European CE industry. Companies such as Veolia and Suez are global leaders in circular economy industries. European companies can also build important supply chains for recyclates and recycled materials as demonstrated by companies such as Umicore and

Fortum. There is a huge scope for growth: only 1% of the global value of trade in secondary goods and materials happens between low-income countries and middle-to-high-income countries.[56] Moreover, trade data indicate that the EU 27 has emerged as the only major supplier with a strong export specialisation in circular economy technologies (Figure 6).[57] This positive specialisation for waste and related technologies is even higher than the positive specialisation for clean-tech in general.

Europe also enjoys a regulatory advantage in a circular economy. The reason is that the EU's standards to increase circularity in its other markets are likely to spread as other countries aim to go circular as well. Many governments around the world are struggling with the problems of increasing amounts of waste, and creating circular economy plans, but there are few international standards available to guide this process. The EU is now already setting global norms for eco-design, repairability, durability and recyclability through its rules on sustainable products spreading to other markets. The "Brussels Effect"[58] of new circularity-focused standards has great potential to improve productivity in the EU and also give European companies an opportunity to get ahead of the game. If the move to circularity stimulates innovation in products that are more durable and resource-efficient, it will create lead markets and European companies will have the edge in designing products that meet the highest global standards.

Taken together, these technological, market supply and regulatory advantages indicate that the EU has a good starting position. However, with other countries like China starting to catch up, the EU should intensify its R&I policies to further strengthen its technological capabilities. The most important step will be to strengthen the demand side factors: To meet the potential for the Circular Single Market to boost the EU's competitiveness, the next Commission will need to build out the institutional and policy infrastructure to address the demand side while framing it intelligently under the headings of the main strategic goals. This strategy will need to include materials efficiency, not only energy. Currently, projections of the economic benefits of the circular economy are not bringing an equivalent scale of investment. In plastics recycling alone, the European Investment Bank has estimated an investment gap of €6.7 – 8.6 billion to achieve EU targets.[59] Policy needs to incentivise investment better, given the potential benefits.

[56] Barrie, J., L. Abdul Latif, M. Albaladejo, I. Baršauskaitė, A. Kravchenko, A. Kuch, et al. (2022) *Trade for an Inclusive Circular Economy* (Royal Institute of International Affairs, 15 June), available at https://doi.org/10.55317/9781784135294

[57] The patent and trade data, is based on classifications used by Walz et al. (2017), Innovations for reaching the green sustainable development goals – where will they come from? International Economics and Economic Policy 14 (3), 684-695 and Gulden, V.S., Ingwersen, K., Gehrke, B., Schasse, U. (2024), Die Umweltwirtschaft in Deutschland, Federal Environmental Agency Germany, available at https://www.umweltbundesamt.de/sites/default/files/medien/11850/publikationen/04_2024_uib_umweltwirtschaft_in_deutschland_0.pdf

[58] Bradford, A. (2020) *The Brussels Effect: How the European Union Rules the World*, 1st edn (Oxford University PressNew York), available at https://doi.org/10.1093/oso/9780190088583.001.0001

[59] EIB (2023) 'Cutting plastics pollution: Financial measures for a more circular value chain', *European Investment Bank*

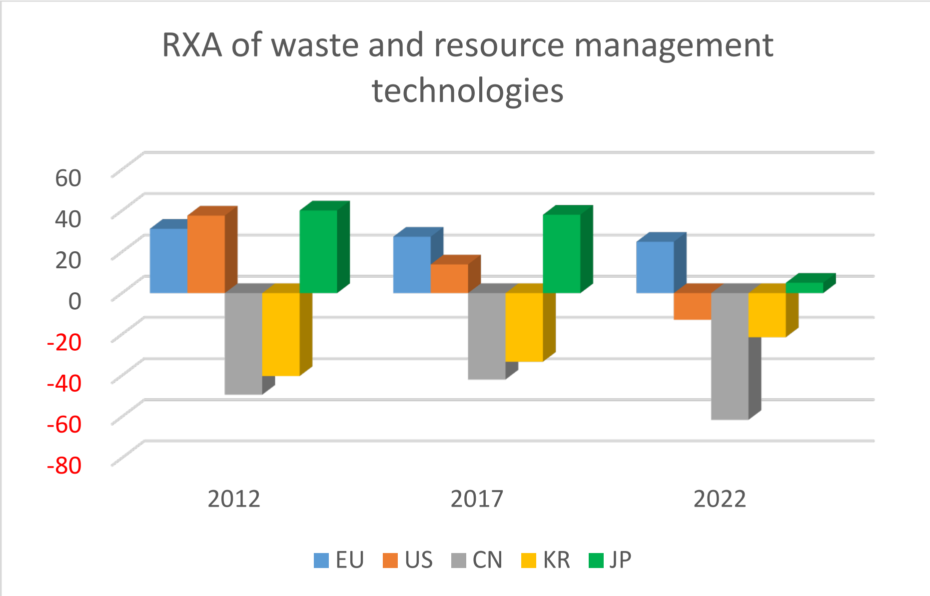


FIGURE 6 - DEVELOPMENT OF RXA OF SELECTED COUNTRIES IN CIRCULAR ECONOMY TECHNOLOGIES. SOURCE: SOURCE: DG RESEARCH AND INNOVATION - COMMON R&I STRATEGY AND FORESIGHT SERVICE - CHIEF ECONOMIST UNIT'S OWN CALCULATION BASED ON BACI DATASET FROM CEPII. NOTE: VALUES ARE IN THOUSANDS OF USD. EU AND WORLD DATA ARE EXPRESSED WITHOUT INTRA-EU TRADE.

The circular economy and a systemic approach to competitiveness

Increasing resource productivity and achieving a decoupling of resource use relative to GDP growth is an important step. However, it still falls short of a systemic approach to competitiveness, which calls for production and consumption systems with significantly reduced absolute material and energy inputs. From such a systemic approach, increasing resource productivity as presented from a traditional perspective of competitiveness is not enough for two reasons. Firstly, increasing productivity does not necessarily call for an absolute reduction in resource use, but can be also achieved with a relative decoupling. Secondly, the system boundary of resource productivity is confined by domestic material consumption (DMC). The DMC measures the domestic extraction of materials and adds to this the physical balance of imported and exported raw materials and goods. A systemic view requires looking at resource use from a broader definition, taking into account global boundaries and the complete material footprint along the value chain of products and services. In particular, it is necessary to take the raw material equivalents into account, which are needed to produce the imported and exported raw materials and goods. A key indicator to include this is the material footprint or raw material consumption of a geographical area, calculated by the global demand for the extraction of materials induced by the consumption of goods and services within a geographical reference area. This indicator has been used within the context of the goals for SDG 12.

The EU 8th Environment Program calls for a significant reduction in raw material use because the extraction and processing of these resources has significant environmental impacts, such as climate change, freshwater use and biodiversity loss. However, the relation of the material footprint with long-term competitiveness has not received much attention yet. However, with the increasing severity of the transgression of planetary boundaries to be felt in the future, it is clear that all major economies will have to operate under the conditions of restricted availability of extracted materials. Under these conditions, economies with lower material footprints will be more competitive, because they have already more adjusted to these constraints.

The total material footprint of Europe and North America has not been changing much in the last 20 years, with strong increases in the other regions of the world.[60] On a per capita basis, the material footprint of high-income and upper-middle-income countries is way higher than that of lower-middle and low-income countries.[61] But even within these country groups, there are substantial deviations. The per capita material footprint in the US is much higher than in the EU 27 or Japan, with China surpassing the EU in the last years (Figure 7). This has also important implications for competitiveness: If we look at the traditional measure of competitiveness as presented in section 1.1, the US leads Europe 27 with regard to labour productivity. But if we look at the material footprint, we see that the US is less competitive than the EU 27.

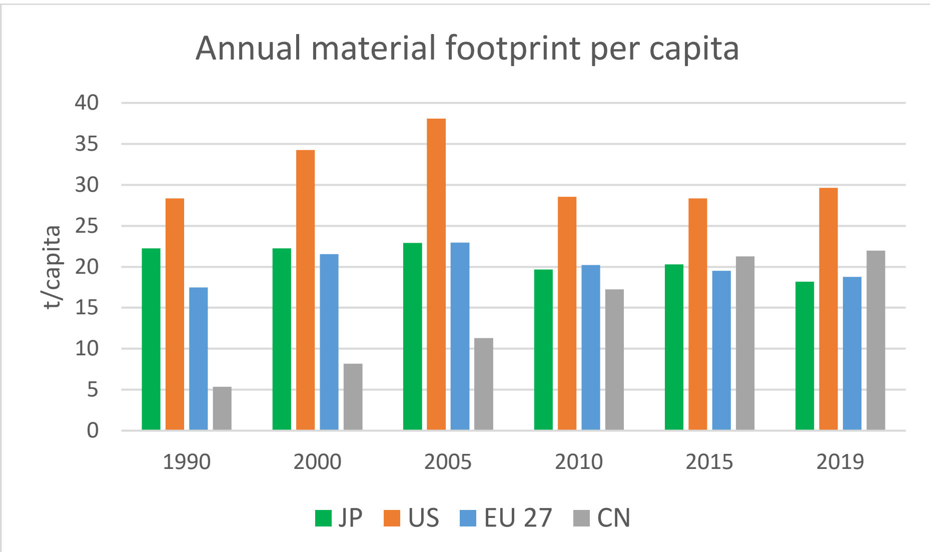


FIGURE 7 - DEVELOPMENT OF MATERIAL FOOTPRINT FOR SELECTED COUNTRIES. SOURCE: AUTHOR'S OWN COMPILATION, BASED ON DATA FROM THE OECD

[60] United Nations Environment Programme (2024): Global Resources Outlook 2024: Bend the Trend – Pathways to a liveable planet as resource use spikes. International Resource Panel. Nairobi. https://wedocs.unep.org/20.500.11822/44901

[61] According to UNEP 2024, the material footprint of high income countries and upper-middle income countries amounted to 24 and 19 tons per capita respectively, compared to a world average of 13 tons/capita.

A systemic view on competitiveness has to account for the changing geopolitical situation. Previous ESIR reports have pointed to the importance of raw materials in a changing geopolitical context, and have called for integrating raw material dependencies into the concept of technology sovereignty.[62] However, ESIR also concluded that "a strategy that builds on broadening the resource base by extracting natural resources from developing countries in the current pattern has no role in a vision of a sustainable European or global economy".[63] Moving towards a circular economy will reduce the need for critical raw materials, some of which are needed also for the increasing demand of climate mitigation technologies, and will therefore make Europe less vulnerable with regard to interruptions in the supply of critical resources. But this benefit of a circular economy not only applies to critical raw materials, that have a higher potential risk of supply.[64] We also have to consider the more general lessons about our ability to identify future risks. Even if we improve our foresight abilities and integrate them more systematically into policymaking, as in the EU's critical raw materials strategy, our ability to foresee risks of supply will always be limited. A circular economy, which reduces raw materials demand not only for pre-identified specific minerals but across the board, will also reduce such unforeseeable risks. Thus, a circular economy is less vulnerable and more resilient to geopolitical changes from a systemic perspective, and therefore also more competitive in a long-term perspective.

A circular economy will affect the trade relations with the exporter countries by reducing the imports of the EU of raw materials from abroad. From the perspective of resource-rich developing economies, natural resource-based sectors such as mining offer the potential of an economic development strategy to build capabilities in these sectors which enable innovation spillovers to other sectors.[65] Thus, a reduction of raw material imports by the EU might be seen by some developing countries as a reduction in economic opportunities.[66] However, a natural resource based innovation strategy can only be successful if it is integrated into the requirements given by planetary boundaries. Thus, moving towards a circular economy the "EU needs to co-design strategies with its trade partners to promote the sustainable use of natural resources and the shift from extractive economies to regenerative economies. This, in turn, can foster well-being and fair distribution of value and income, and foster practices for sustainable commodity trading in core resources and materials".[67] At the same time, Europe also needs new policy instruments to stimulate both European

[62] European Commission, Directorate-General for Research and Innovation, Dixson-Declève, S., Renda, A., Schwaag Serger, S. et al., *Research, innovation, and technology policy in times of geopolitical competition*, Publications Office of the European Union, 2023, https://data.europa.eu/doi/10.2777/745596

[63] European Commission, Directorate-General for Research and Innovation, Dixson-Declève, S., Renda, A., Isaksson, D. et al., *Transformation in the poly-crisis age*, Publications Office of the European Union, 2023, https://data.europa.eu/doi/10.2777/360282

[64] COM(2020) 474 - Critical Raw Materials Resilience: Charting a Path towards greater Security and Sustainability, avalable at https://ec.europa.eu/docsroom/documents/42849

[65] Andersen, A. D., Marìn, A., & Simensen, E. O. (2018). Innovation in natural resource-based industries: a pathway to development? Introduction to special issue. Innovation and Development, 8(1), 1–27. https://doi.org/10.1080/2157930X.2018.1439293.

[66] Usman, Z.; Abimbola, O.; Ituen, I. (2021): What Does the European Green Deal Mean for Africa? Washington, D.C.: Carnegie Endowment for International Peace.

[67] European Commission, Directorate-General for Research and Innovation, Dixson-Declève, S., Renda, A., Isaksson, D. et al., *Transformation in the poly-crisis age*, Publications Office of the European Union, 2023, https://data.europa.eu/doi/10.2777/360282

manufacturers and strategic cooperations with non-European manufacturers to move towards more sustainable raw material supply and use. In earlier work, ESIR has indicated that a carbon border adjustment for sustainable raw materials can support this.[68]

Additional systemic aspects of competitiveness may arise with regard to the distribution of value-added activities. Circular economy approaches require certain economic activities which are undertaken in closer spatial proximity to the population than the production of goods. This holds for example for the collection of waste to be recycled, but also for repair activities. This indicates that a circular economy might benefit from a more equal distribution of economic activities within the EU. Moreover, a circular economy is not restricted to technological innovations but also requires social innovations such as sharing and repairing. The rationale for these strategies goes beyond pure environmental and economic dimensions and also involves social attractiveness. Fostering social innovations requires new forms of policies. Specifically, the outcome of policies to foster social innovations are much more difficult to project, and can only be seen after considerable time. At the same time, social innovation is crucial to ensure the deployment of new technologies in society. Thus, systemic R&I policies fostering such approaches need a much longer horizon than the typical projects funded with European programs and involve substantially higher risk-taking.

GREEN HYDROGEN

Many scenarios describing a sustainable future are based on renewable energy from wind and sun providing most of our energy. Green hydrogen is seen as a solution for those moments when the supply from wind and sun is not sufficient to fulfil demand and for sectors that are difficult to electrify. More specifically, green hydrogen is needed to decarbonise otherwise difficult-to-decarbonise end uses in heavy industry (as feedstock and for high-temperature processes) and for seasonal energy storage. It could however be used for many other end uses (in transport, for space heating) which explains some of the hydrogen hype. Green hydrogen technology is thus envisioned to play a key systems role in realizing clean energy systems.

Hydrogen has long been used in some industries, e.g., in refinery, process industry and nuclear power and is typically produced from fossil fuels (grey hydrogen). Green hydrogen is produced from water using electrolysers that run on renewable electricity. Currently, only one per cent of hydrogen is produced with renewable energy. The future demand for green hydrogen will depend on how the green transition affects the structure of the EU economy, as some energy-intensive industries may relocate to countries where there is abundant renewable energy available.

Green hydrogen and productivity growth

The promise of green hydrogen is that it will be able to provide a cost-effective solution to fulfil the energy needs of the energy-intensive industry in the future. These visions typically assume that the structure of the economy will remain unchanged even with large changes in the energy landscape. The key policy goal of hydrogen-related policy is cost reduction.

[68] European Commission, Directorate-General for Research and Innovation, Dixson-Declève, S., Renda, A., Isaksson, D. et al., *Transformation in the poly-crisis age*, Publications Office of the European Union, 2023, https://data.europa.eu/doi/10.2777/360282

Increasingly, however, the considerations here are not only economic but also strategic, which industries are needed in Europe to remain competitive in the long term. While there are some markets where green hydrogen is arguably the best or only option, there are competing alternatives in many other markets (direct electrification, batteries). There is thus large uncertainty about the future market size for green hydrogen. Despite this uncertainty, the European Hydrogen Bank, a financing instrument received broad interest from a range of countries and sectors.[69]

Electrolysers produce hydrogen from water using electricity and are a key technology for green hydrogen production. In line with a productivity perspective, most innovation efforts focus on bringing down the cost of electrolysers. It is expected that energy as a key factor for production will remain relatively expensive in Europe, also because large investments in infrastructure and in creating resilience in the energy system are needed. While in an ideal type situation, hydrogen powered energy plants will run only sporadically. Demand reduction and a better match between demand and supply through demand-side management or flexibility markets will reduce the role of hydrogen in the future energy system. This does create a challenge of financing green hydrogen developments and a challenge to avoid lock-in into an energy system with a larger role for hydrogen but also a much larger energy use. Specifically, as the production of green hydrogen is very energy intensive the build-out of a resource-efficient green hydrogen system should prioritize hydrogen projects that offer flexibility, running only when abundant renewable energy is available. Moreover, it should prioritize projects for which a sustainable long-term business case is likely.

Several EU countries therefore are exploring the option of importing green hydrogen from countries where there is abundant renewable energy, (for example in the Middle East and North Africa). While these countries may indeed have the land available as well as favourable renewable energy conditions, water scarcity may be a problem. Moreover, these countries may require renewable energy resources for their own climate and development goals. For long-distance transport, the green hydrogen can be converted to other more efficient energy carriers in an energy-intensive process. Depending on the distance and the foreseen end use, the economic and environmental costs and benefits for these options diverge[70] but may be quite high.

Green hydrogen first mover advantages and lead markets

Several EU countries in Northwest Europe but also Portugal and Spain have developed ambitious hydrogen strategies that aim for global leadership in green hydrogen. In these visions, green hydrogen is not only an essential part of a sustainable energy system but also contributes to goals of energy security and industry leadership. Typical drivers of such visions are access to abundant renewable energy (for example wind at sea) and large energy-intensive industries that often emerged in part because of access to cheap energy. Despite the large number of green hydrogen projects, implementation lags behind. IEA explains this by the observation that green hydrogen development goes beyond technology development but requires the coordinated build-up of a complex value chain.

New application areas of hydrogen highlight the need for new governance and knowledge development. To enable societal implementation and deployment of green hydrogen, it is

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[69] https://energy.ec.europa.eu/topics/energy-systems-integration/hydrogen/european-hydrogen-bank_en

[70] de Kleijne, K., de Coninck, H., van Zelm, R., Huijbregts, M. A., & Hanssen, S. V. (2022). The many greenhouse gas footprints of green hydrogen. *Sustainable Energy & Fuels*, *6*(19), 4383-4387.

necessary to develop existing and new standards, regulations and permitting processes. This development should include the complete value chain for green hydrogen, across both sectors and geographies. Green hydrogen is a new and partially unknown area. Development and dissemination of new knowledge among public authorities will be required for them to be able to analyse and regulate the industry and for private actors to exploit business opportunities and build new markets. Such knowledge includes technology understanding, as well as how hydrogen can be integrated into the energy system and used in industrial processes. Green hydrogen deployment is cross-sectoral and illustrates the need to strengthen coordination and competence at international, national, regional and local levels.

New technologies and new business models increasingly require that different stakeholders and producers connect to use each other's side flows or use residual products. Feasibility for one individual firm's projects and profitability can be completely dependent on other firms successfully implementing their projects, as their individual contributions constitute vital parts of a single new value chain. Green hydrogen constitutes an example of this. Achieving resource-efficient and economically viable green hydrogen projects requires that side flows are used and that hydrogen becomes an integral part of the energy system, for example by utilising residual heat or contributing with balancing services in the electricity market.

A shift to green hydrogen industrial ecosystems, at large scale, requires in addition to the establishment of new industrial facilities to produce, store, and transfer hydrogen, also increased water usage, electricity production facilities and an expedient power grid. Myriad public authorities and private actors must be involved in the same hydrogen project thus entailing a need for a systematic sector-wide governance approach. An acceleration of the green transition requires that working methods of local and central public agencies are developed in parallel with the introduction and deployment of new technical solutions.

The development of green hydrogen-based industrial processes is driven by climate goals and industrial policy, which in turn gives rise to a potential premium market for carbon dioxide-neutral products. A frontrunner example here is the first Swedish fossil-free steel production, that succeeded in getting a sufficient price premium for[71] using green hydrogen on the world market and is embedded in an economically sustainable value chain with existing stakeholders. Fossil-free steel is produced using hydrogen instead of coal in the iron ore reduction process. The result is a removal of the fossil carbon emissions and instead water vapour is emitted. Investing in developing climate-neutral products may provide a financial impact high enough to positively affect further investment along entire value chains to initiate the production of climate-neutral materials and inputs. This is facilitated by the fact that the cost increase for an end product that uses fossil-free materials, such as a car, is only approximately one per cent. There are therefore good prospects of charging a price-premium that covers the extra costs associated with the manufacturing of fossil-free products.

While there thus seem to be opportunities to develop a European green hydrogen sector, the question remains as to how well Europe is positioned to develop strong capabilities in the technologies required for systemically efficient green hydrogen production and if these could be successfully exported to other countries that seek to decarbonize. This point is strongly supported by data on innovation indicators: Europe has been able to even increase its world share in hydrogen technologies (Figure 8a) and has strongly increased its RPA (Figure 8b).

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[71] *Royal Swedish Academy of Engineering Sciences (IVA), 2022. Hydrogen and its role in the electrical system - synthesis report from IVA's project the role of hydrogen in a fossil-free society. [202205-iva-vatgasprojektet-syntesrapport.pdf)]*

Compared to main competitors such as the US and China, the technological knowledge base in hydrogen patents is very strong. Trade data supports this view (Fig. 9)[72]. Europe is head-on with China, but way ahead of the other competitors with regard to exports, and its very high revealed export advantage (RXA) indicates that Europe is particularly strong in this technology (Figure 9). [73]

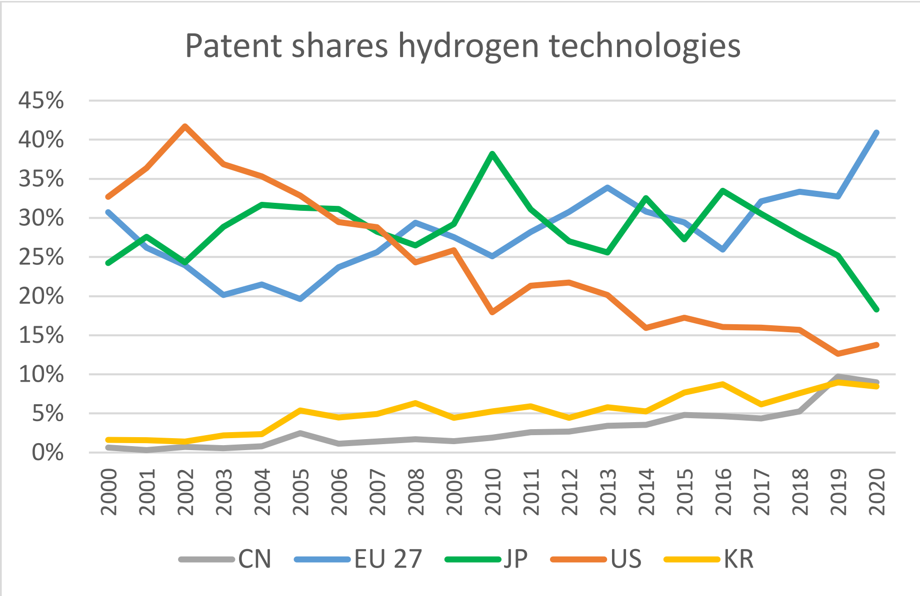

Figure 8a and b - Development of patent shares (5a) and RPA (5b) of selected countries in hydrogen technologies. Source: Author's own compilation using calculations from Fraunhofer ISI, based on Patstat data

[72] *The classification scheme used for hydrogen technology trade data if from Müller, V. P., Eichhammer, W. (2023), Economic complexity of green hydrogen production technologies - a trade data-based analysis of country-specific industrial preconditions, Renewable and Sustainable Energy Reviews 182, 113304*

[73] European Commission, Directorate-General for Research and Innovation, Dixson-Declève, S., Dunlop, K., Renda, A. et al., Industry 5.0 and the future of work – Making Europe the centre of gravity for future good-quality jobs, Publications Office of the European Union, 2023, https://data.europa.eu/doi/10.2777/685878

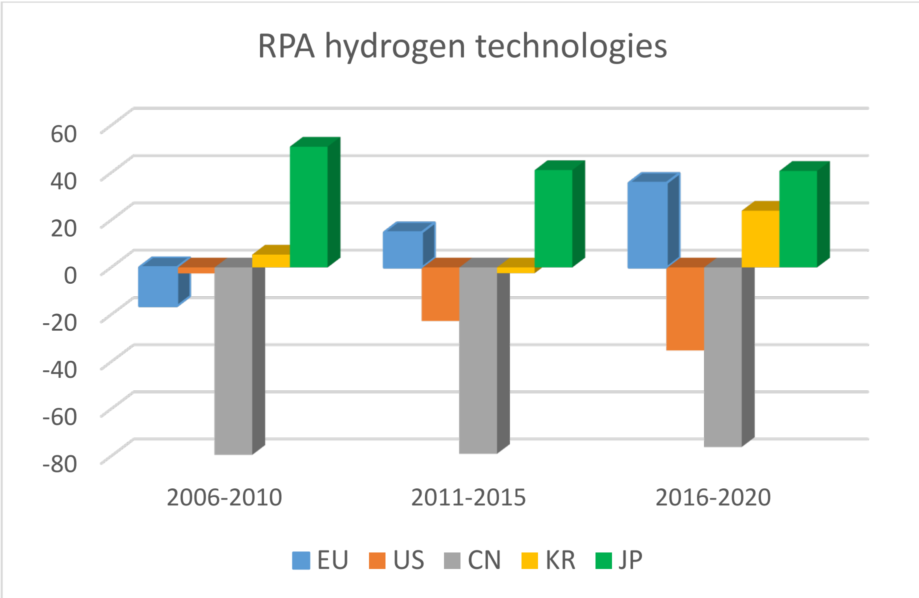

Figure 9 - RPA for hydrogen technologies. Source: Author's own compilation using calculations from Fraunhofer ISI, based on Patstat data

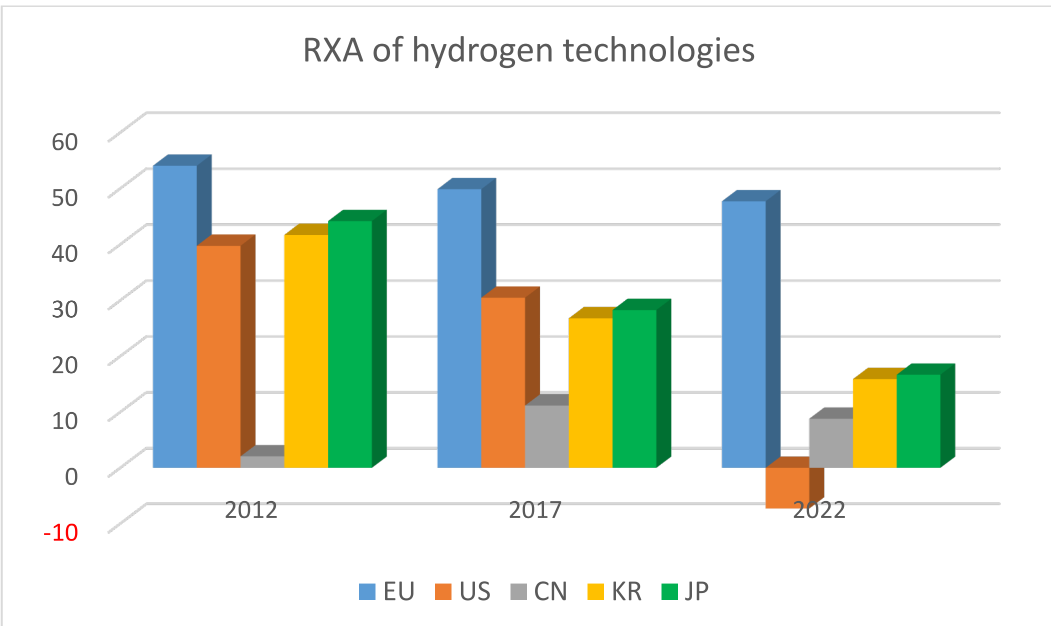

Figure 9 - RXA for hydrogen technologies. Source: DG Research and Innovation - Common R&I Strategy and Foresight Service - Chief Economist Unit's own calculation based on BACI dataset from CEPII. Note: Values are in thousands of USD. EU and World data are expressed without intra-EU trade.

Green hydrogen and a more systemic approach to competitiveness

The Clean Hydrogen mission aims to increase the cost-competitiveness of clean hydrogen by reducing end-to-end costs to a tipping point of 2 USD/kg by 2030. While this mission targets different system elements, R&D, developing demand and supply, and recognises the human resource agenda, it pays less attention to the global justice dimension. Such a systems approach is needed as electrolysers need to run on renewable energy to avoid increasing CO2 emission, renewable energy needs to be in demand to avoid curtailment and declining business models, and demand for hydrogen needs to be present to close the business case for green hydrogen. Successful build-out of a green hydrogen system also requires infrastructure (both in terms of hydrogen pipelines and reinforcement of the electricity grid), handling of side-flows such as heat and supporting innovations in governance and regulation.

While the need for system-building policies thus seems well-addressed, the more overarching system-level question of 'what is the role of green hydrogen' in a future competitive EU economy remains unanswered. As infrastructure-based industries come with a large risk of lock-in, this needs to be addressed. The related questions of which parts of the value chain could be developed within the EU, and what other countries could be attractive, mutually beneficial trade partners thereby need to be answered from a systemic competitiveness perspective that goes beyond economic benefits for the EU. Even if green hydrogen production is enlarged within Europe, there still will be a need for imports. This raises the question of security of supply from the countries exporting hydrogen to Europe.[74] But even for hydrogen to be produced within Europe by European-manufactured hydrogen technologies, the security of supply requires attention. The production of electrolyzers, for example, requires raw materials such as Iridium, Scandium, Yttrium and Zirconium, and with increasing demand, the supply of these strategic materials may become a concern.[75]

Another need for a systemic perspective arises with regard to the sustainability of green hydrogen supply. To ensure that the hydrogen is produced from renewable energy sources and achieves at least 70% greenhouse gas emissions savings, the Commission adopted in June 2023 two delegated acts, which apply to both domestic and international producers.[76] Hydrogen, also if imported from outside the EU, should not only be green, but also produced according to additional sustainability requirements. A specific task for a systemic R&I policy is to come up with evaluation methodologies and tools which enable a thorough sustainability assessment, and usage of these rules in certification and standard setting. Finally, the systemic nature of increasing competitiveness in green hydrogen requires looking beyond

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[74] Sutrisno, A., Nomaler, Ö., & Alkemade, F. (2021). Has the global expansion of energy markets truly improved energy security? *Energy Policy*, *148*(A), Article 111931. https://doi.org/10.1016/j.enpol.2020.111931

[75] Marscheider-Weidemann et al. (2022), Raw materials for emerging technologies 2021, German Minerals Resources Agency, Berlin, available at https://www.deutsche-rohstoffagentur.de/DE/Gemeinsames/Produkte/Downloads/DERA_Rohstoffinformationen/rohstoffinformationen-50-en.pdf?__blob=publicationFile&v=2; Eikeng, E., Makhsoos, A., Pollet, B. G. (2024), Critical and strategic raw materials for electrolysers, fuel cells, metal hydrides and hydrogen separation technologies, International Journal of Hydrogen Energy 71, 433-464

[76] COMMISSION DELEGATED REGULATION (EU) 2023/1184, available at https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32023R1184

R&I policies. It is as much a question of energy policy, industrial policy and trade policy, and integration of these policy domains with R&I policies is a central factor for a successful systemic competitiveness policy.

CONCLUSIONS

This report argues that a more systemic approach to research and innovation policy is needed to foster a competitive European economy. In our long-term view, we see a competitive EU as a forerunner in maximising the societal value gained by using the Earth's limited natural resources while at the same time minimising the environmental and social costs of this use. Such a systemic approach not only recognizes that surpassing planetary boundaries is a threat to wellbeing, but also that resource scarcity and supply disruptions will increasingly affect the economy. A competitive advantage in resource productivity thereby not only contributes to well-being but also to policy goals on strategic autonomy. In addition to a focus on well-being and sustainability, our long-term view also explicitly includes innovation policies targeting dynamic competitiveness, i.e., the continued ability to develop future key technologies that address societal challenges.

Such a systemic approach to competitiveness policy acknowledges that the EU economy operates as a complex adaptive system encompassing a number of interrelated and sometimes conflicting challenges including competitiveness, social cohesion, economic security and sustainability. A systemic R&I policy then starts from those areas where the EU has a comparative advantage *and* that align with well-being and sustainability goals. Green tech and innovations for circularity are such fields, where the relative resource scarcity of the EU can be a driver to create comparative advantage and ensure economic security. It then horizontally integrates and coordinates R&I policy to translate the knowledge advantages into globally competitive EU industries and benefits for EU citizens. This explicitly includes policies that seek to develop, attract and retain the relevant skills, policies that stimulate innovation in services, regulations that accelerate diffusion and policies and regulations for market development.[77]

The case studies presented here on the circular economy and hydrogen demonstrate that key elements of the European Green Deal offer a triple potential to improve competitiveness: They contribute to improving the competitiveness of Europe by increasing productivity in the short run, open up to further increase existing first mover advantages and to exploit these in the medium perspective, and increase systemic competitiveness by strengthening resilience in times of geopolitical changes in the long term. Pushing further ahead with the Green Deal is a win-win strategy with regard to competitiveness. ESIR therefore sees a need to further increase the allocation of funds towards Green Deal topics in Framework Program 10. A shift towards other domains at the cost of these topics would be counterproductive to European competitiveness in the medium and long term.

Making Europe more competitive will also require fostering critical technologies, and the further development of the governance of technologies - a specific topic ESIR will address with a separate report. However, it is clear that necessary improvements, e.g. with regard to digitisation and production, require a much more systemic approach to competitiveness than only productivity improvements. This clearly can be seen with regard to production and AI: ESIR in its study on Industry 5.0, a transformative vision for Europe[78] calls for "a deep

[77] Klemun, M.M., Kavlak, G., McNerney, J. *et al.* Mechanisms of hardware and soft technology evolution and the implications for solar energy cost trends. *Nat Energy* 8, 827–838 (2023). https://doi.org/10.1038/s41560-023-01286-9

[78] European Commission, Directorate-General for Research and Innovation, Renda, A., Schwaag Serger, S., Tataj, D. et al., Industry 5.0, a transformative vision for Europe – Governing systemic transformations

transformation of the economy at the global level by shifting beyond GDP determined growth and embracing an Industry 5.0 programme" and proposes an Industry 5.0 Action Plan. The systemic competitiveness perspective underlines the need for such an Action Plan also from the specific goal of competitiveness. The Industry 4.0 approach is not compatible with the achievement of sustainable economic competitiveness. Systemic competitiveness requires moving towards the human-centric approach of Industry 5.0[79].

towards a sustainable industry, Publications Office of the European Union, 2021, https://data.europa.eu/doi/10.2777/17322

[79] European Commission, Directorate-General for Research and Innovation, Dixson-Declève, S., Dunlop, K., Renda, A. et al., Industry 5.0 and the future of work – Making Europe the centre of gravity for future good-quality jobs, Publications Office of the European Union, 2023, https://data.europa.eu/doi/10.2777/685878

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This policy brief argues for a systemic approach to R&I policy in enabling an economic competitiveness articulated with the environmental and societal sustainability goals. It looks into the role of R&I policy in enabling the competitiveness of the EU economy while pointing out the challenges in the current competitiveness paradigm. Two case studies illustrate the advantages and challenges faced by Europe in reaching competitiveness in the face of global crises: one on green hydrogen and one on the circular economy.

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