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ASSESSMENT OF TECHNOLOGY TRANSFER PRODUCTS
ENEA's Contribution to the Sustainable Development Goals

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SUMMARY

1 INTRODUCTION

We live in an increasingly complex world. Although unprecedented levels of economic growth have been achieved in recent decades and significant progress has been made on several key issues of human development, these achievements have partly obscured deep structural weaknesses in the current development model. Such vulnerabilities are generating a growing number of environmental and social pressures, which pose an increasing threat to our way of life and make the global context less sustainable and less conducive to economic activity.

On the one hand, significant progress has been made in recent decades: millions of people have been lifted out of extreme poverty; access to education has increased substantially; the spread of mass communication and information technologies, global interconnectedness, and increasingly advanced scientific and technological discoveries have accelerated human progress and supported the development of knowledge-based societies [1].

On the other hand, despite the efforts of the international community, billions of people continue to be deprived of a dignified life. Inequality is increasing both between countries and within them, and substantial disparities persist in terms of opportunities, wealth, and power, including gender inequality.

Moreover, the progress achieved is increasingly threatened by numerous factors, among which climate change, the growing frequency of natural disasters, the depletion of natural resources, and the negative impacts of environmental degradation—such as desertification, drought, water scarcity, and biodiversity loss—are particularly prominent. These challenges are further compounded by the rapid increase in conflicts, humanitarian crises, and the resulting forced displacement of populations, which collectively expand the range of threats humanity is required to confront [1].

As a result, the need has emerged to adopt faster and more ambitious actions and policies to enable the economic and social transformation required to achieve sustainable development, moving towards a growth model that meets present needs without compromising the ability of future generations to meet their own.

Within this context, the 2030 Agenda for Sustainable Development was adopted in 2015 by 193 UN Member States. It represents a global action plan consisting of 17 Sustainable Development Goals (SDGs) and 169 targets to be achieved by 2030. The Agenda aims to eradicate poverty, protect the planet, and ensure prosperity for all, and is based on five key dimensions—the so-called “5 Ps”: People, Planet, Prosperity, Peace, and Partnership.

The SDGs are not limited to environmental concerns but provide a universal and measurable framework for addressing global challenges, including poverty, climate change, inequality, and environmental protection. They serve as a guiding compass for policymaking, with the objective of preserving the planet for future generations.

In recent years, sustainability has assumed an increasingly central role in corporate strategies worldwide. Companies play a crucial role in achieving the Sustainable Development Goals, transforming sustainability from a regulatory constraint into a strategic lever for growth and competitiveness. Integrating the principles of the 2030 Agenda into business models allows firms to optimize resources, reduce environmental impact, and respond to evolving market demands through innovative solutions. Beyond being a responsible choice, sustainability represents a tangible advantage for companies, generating measurable benefits both in economic and reputational terms.

The growing attention to environmental, social, and governance dimensions has led to the widespread adoption of ESG (Environmental, Social, Governance) criteria, which today constitute a fundamental reference for assessing organizational performance and engagement. The adoption of ESG criteria goes beyond the implementation of environmentally friendly practices or philanthropic initiatives, requiring a comprehensive rethinking of corporate strategy aimed at integrating environmental, social, and ethical objectives into decision-making processes and business models.

ESG objectives are closely linked to the Sustainable Development Goals. In particular, they contribute significantly to the achievement of several SDGs, including access to clean energy (SDG 7), decent work and economic growth (SDG 8), industry, innovation, and sustainable infrastructure (SDG 9), responsible consumption and production (SDG 12), climate action (SDG 13), strong institutions (SDG 16), and effective partnerships (SDG 17) [2]. In this context, sustainability represents not only a regulatory requirement but also an opportunity to enhance competitiveness, attract investment, mitigate risks, and foster the adoption of innovative solutions.

Within this framework, innovation emerges as a key factor in supporting the economic and social transformation required to achieve the SDGs. The link between innovation, economic progress, and social development is widely recognized and explicitly addressed by SDG 9, which aims to promote sustainable industrialization, resilient infrastructure, and innovation-driven processes.

Historically, the development and diffusion of new technologies have contributed to productivity growth, improved living conditions, and the strengthening of economic structures. Today, emerging and frontier technologies—such as artificial intelligence, biotechnology, advanced materials, and solutions for the energy transition—offer even greater potential to address contemporary environmental and social challenges, while also generating new complexities and interconnections among development objectives [3].

Within this context lies the concept of innovation, and in particular that of technology transfer.

Technology transfer plays a crucial role in transforming the outcomes of scientific research into concrete applications, facilitating the diffusion of innovation within the productive system. An appropriate regulatory and institutional framework—especially with regard to intellectual property—helps make innovation a more systematic and reliable process, encouraging investment in research and development and accelerating the dissemination of technologies.

This thesis aims to demonstrate how technology transfer represents a strategic lever for achieving SDG 9 (Industry, Innovation, and Infrastructure) and, indirectly, numerous other SDGs, thanks to its ability to connect science, technology, and industrial application. However, the academic literature still lacks a shared methodological approach for systematically assessing the links between innovation, technology transfer, and the SDGs, as well as for concretely measuring the interactions among different sustainable development goals.

In light of the theoretical framework and contextual analysis discussed above, this study aims to answer the following research questions:

1. What role does innovation play in advancing sustainable development, with specific reference to SDG 9 and its interlinkages with other Sustainable Development Goals?
2. How can technology transfer act as a key enabler of sustainable innovation and contribute to the achievement of the objectives of the 2030 Agenda?

3. How do ENEA's technology transfer outputs contribute to the achievement of the Sustainable Development Goals, and how can this contribution be assessed?

1.1 GUIDE TO THE THESIS

To address the research questions, the thesis begins with an analysis of the Sustainable Development Goals, introducing the conceptual and methodological framework necessary to understand their current state of implementation. In particular, it provides an overview of the global situation and the Italian context, highlighting the complexity of SDG evaluation systems and the challenges related to data availability and comparability.

Subsequently, the analysis focuses on the Italian context, introducing the National Strategy for Sustainable Development for the 2030 Agenda. This strategy aims to achieve the SDGs through the identification of strategic actions that account for interactions among different goals, adopting a systemic and integrated approach.

The thesis then explores the role of innovation in progress towards the SDGs, with particular attention to the innovation dimension of SDG 9—Industry, Innovation, and Infrastructure—by analyzing its state of implementation and key challenges within the Italian context.

A central aspect emerging from the analysis concerns the interconnections among the SDGs. Innovation generates cross-cutting effects across multiple sustainable development objectives, producing both synergies and trade-offs. The nature of these relationships is crucial in determining whether an innovation process can be considered genuinely sustainable.

The thesis subsequently focuses on technology transfer as one of the main drivers of innovation. Technology transfer exhibits strong potential as a lever for innovation-driven impact, capable of influencing industrial sectors and improving quality of life. The objective is therefore to analyze the relationship between technology transfer and SDG 9, as well as the contribution technology transfer can make to the promotion of sustainable innovation.

The literature review reveals that there is still no shared methodological approach for systematically assessing the connections between innovation, technology transfer, and the SDGs, nor for concretely measuring the interactions among the different sustainable development goals.

Given the breadth of the topic, the study focuses on the Italian context, which is characterized by an innovation system still affected by numerous structural and operational challenges.

The ENEA case study—ENEA being the Italian National Agency for New Technologies, Energy, and Sustainable Economic Development—fits within this framework, as the Agency operates in the fields of research and innovation and supports, among other activities, technology transfer and patenting processes. ENEA therefore represents a particularly relevant case for the proposed analysis.

Specifically, ENEA's technology product catalogue, the MATRICS database, aims to enhance the value of innovative technologies and technological proposals developed within the organization, fostering both internal collaborations and partnerships with external stakeholders. The technological products included in the database will be analysed through a questionnaire focused on the SDGs and the National Strategy for Sustainable Development, with the objective of assessing the contribution of ENEA technologies—as outputs of technology transfer—to the achievement of the Sustainable Development Goals.

2 SUSTAINABLE DEVELOPMENT GOALS

Also known as Global Goals, they were adopted by the United Nations in 2015 as an urgent call for action for a sustainable development by 2030. All countries are involved, both developed and developing, in a global partnership view. The goals are founded on the principle that ending poverty, reduce inequalities and other deprivations, together with improving health and education, must go hand-in-hand with strategies to protect the environment – land and waters – and contrast climate change. In fact, the 17 SDGs presented in the Agenda 2030 for Sustainable Development are integrated to ensure a development that will balance social, economic and environmental sustainability, so that by 2030 all people will enjoy peace and prosperity.

The SDGs build on decades of work by countries and the UN, starting in 1992 at the Earth Summit in Rio de Janeiro (Brazil) with the first agenda, the Agenda 21.

Agenda 21 is a comprehensive plan of action to be taken globally, nationally and locally adopted by more than 178 Governments and organizations of the United Nations System, where the number *21* referred to our century as the final aim of the Agenda was to prioritize the kinds of emergencies characterizing our times on the climatic-environmental and socio-economical fields.

In September 2000, during the Millennium Summit at UN Headquarters in New York, Member States elaborated the Millennium Declaration that contains eight Millennium Development Goals (MDGs) to reduce extreme poverty by 2015.

The full implementation of Agenda 21, the Program for Further Implementation of Agenda 21 and the Commitments to the Rio principles, were strongly reaffirmed at the World Summit on Sustainable Development (WSSD) held in Johannesburg, South Africa from 26 August to 4 September 2002, including more emphasis on multilateral partnerships.

In June 2012 the process to develop a set of SDGs built on the previous MDGs started during the United Nations Conference on Sustainable Development when Member States adopted the document “The Future We Want”. The Rio +20 outcome also contained other measures for implementing sustainable development, including the establishment of the UN High level Political Forum on Sustainable Development, future programs of work in development financing, small island developing states and more, in 2013, the General Assembly set up a 30-

member Open Working Group to develop a proposal on the SDGs, while in January 2015, the General Assembly began the negotiation process that culminated in the adoption of the **2030 Agenda for Sustainable Development**.

2015 was a landmark year for multilateralism and international policy shaping, as it was the year of adoption of several international treaties, such as the Paris Agreement on Climate Change.

In September 2024, at the UN Summit of the Future, the UN member states reaffirmed their commitment to the SDGs and effective multilateralism, adopting by consensus the *Pact for the Future, Global Digital Compact and Declaration on Future Generations*. The Pact calls for 56 actions related to SDG implementation, peace, and collective security, including the transformation of the multilateral system and reform of the international financial architecture.

Although the SDGs are not legally binding, governments are expected to take ownership and establish national frameworks for achieving the 17 goals. Nowadays, the annual High-level Political Forum on Sustainable Development serves as the central UN platform for the follow-up and review of the SDGs.

2.1 THE 17 SDGS

All SDGs are integrated and indivisible and balance the three dimensions of sustainable development: the economic, social and environmental.

Figure 1: The 17 Sustainable Development Goals by the UN

Goal 1. End poverty in all its forms everywhere.

Goal 2. End hunger, achieve food security and improved nutrition and promote sustainable agriculture.

Goal 3. Ensure healthy lives and promote well-being for all at all ages.

Goal 4. Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all.

Goal 5. Achieve gender equality and empower all women and girls.

Goal 6. Ensure availability and sustainable management of water and sanitation for all.

Goal 7. Ensure access to affordable, reliable, sustainable and modern energy for all.

Goal 8. Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all.

Goal 9. Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation.

Goal 10. Reduce inequality within and among countries.

Goal 11. Make cities and human settlements inclusive, safe, resilient and sustainable.

Goal 12. Ensure sustainable consumption and production patterns.

Goal 13. Take urgent action to combat climate change and its impacts.

Goal 14. Conserve and sustainably use the oceans, seas and marine resources for sustainable development.

Goal 15. Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss.

Goal 16. Promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable and inclusive institutions at all levels.

Goal 17. Strengthen the means of implementation and revitalize the Global Partnership for Sustainable Development.

2.1.1 Current state of SDGs

The UN draws up every year a Sustainable Development Goals Report to track the progresses, at a global level. For this reason, data systems play a key role as data are needed by Governments to identify problems early, allocate resources effectively or demonstrate accountability.

Over the past decade, data availability for SDG monitoring has improved, yet major gaps remain, underscoring the need for stronger financial support for data infrastructure. Because outcome-based data are often outdated or incomplete—and because meaningful changes may take years to emerge—such statistics frequently fail to capture the current policy landscape or reflect ongoing commitments to the SDGs and effective multilateralism.

The SDGs are monitored at various levels: global, regional, national, local and thematic. In the European Union, the European Commission contributed to the UN's global SDG monitoring in 2023 through the first EU voluntary review, reflecting on the collective effort of the EU towards implementing the SDGs. Then, Each Member State can submit to the UN a Voluntary National Review assessing their progress and challenges in implementing the SDGs, that are presented at the high-level political forum of the UN.

As the UN itself states, they have set out a supremely ambitious and transformational vision, while the 2030 deadline is now only 5 years apart. The 2025 progress assessment issued by the UN, reveals that the world remains far off track from achieving the 2030 Agenda.

According to the UN 2025 SDGs Report, 48 per cent of targets show insufficient progress, including 31 per cent with only marginal gains and 17 per cent with no progress at all. Most concerning, 18 per cent of targets have regressed below 2015 baseline levels.

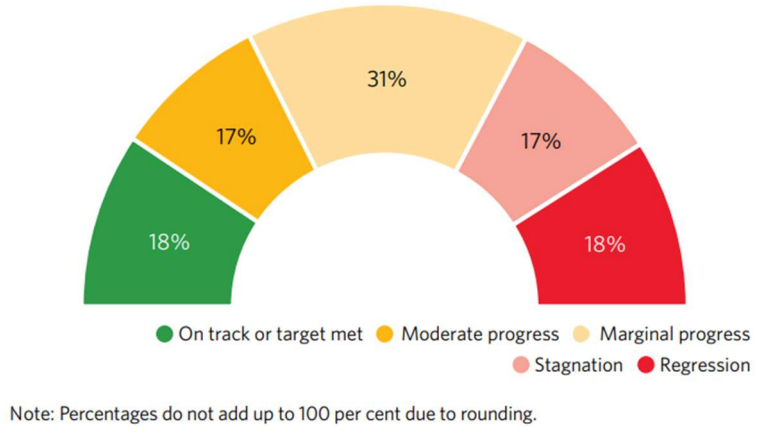


Figure 2: Overall progress targets based on 2015-2025 global aggregate data from [4]

These progresses can vary a lot depending on the goal, target, and of course Country.

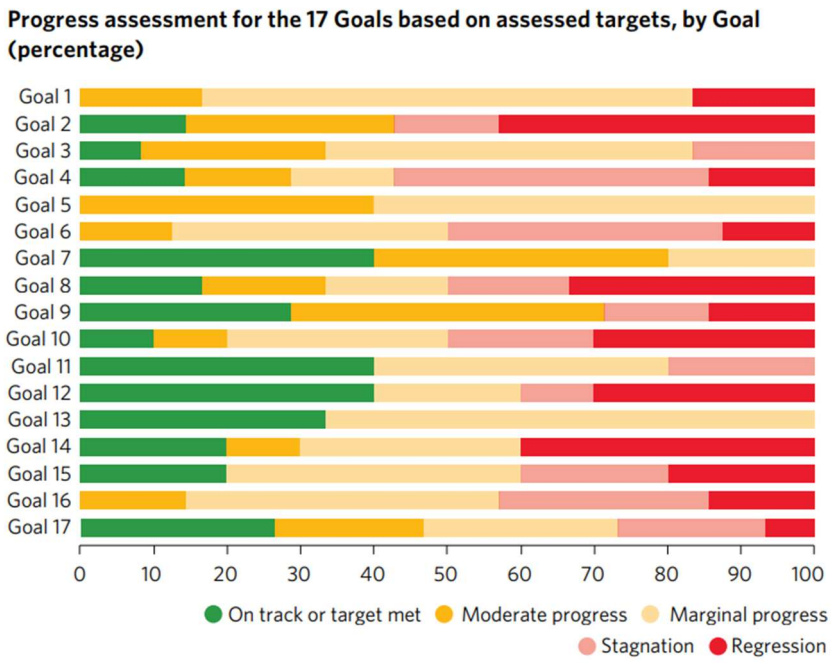


Figure 3: SDGs progress assessed in the UN Report [4]

Some national and local successes may be hidden by global trends, but they represent a virtuous example for others to follow. Progress in each SDG is presented for different country groupings in the next figure:

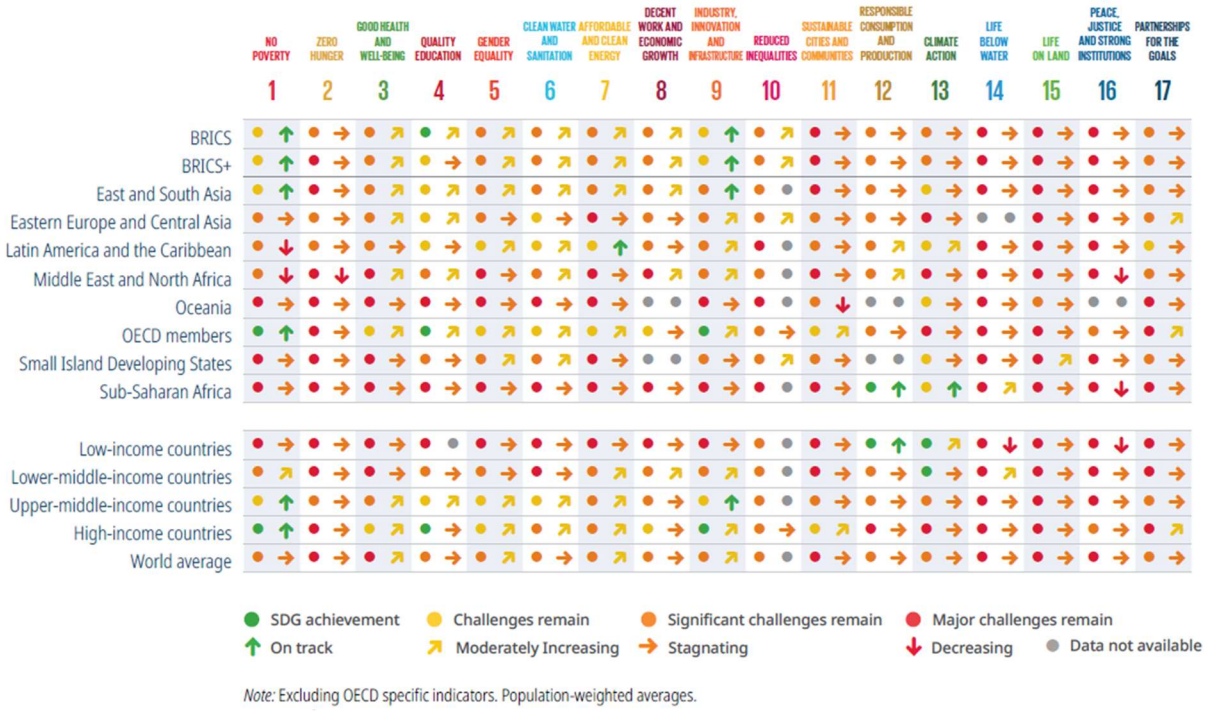


Figure 4: 2025 SDG dashboards by region and income group (levels and trends). Source [5]

By contrast, the 2025 SDG Index Ranking provides a single composite measure that aggregates all goals into an overall performance score. In this way, we can compare countries globally and identify sustainable development leaders.

Rank	Country	Score
1	Finland	87.0
2	Sweden	85.7
3	Denmark	85.3
4	Germany	83.7
5	France	83.1
6	Austria	83.0
7	Norway	82.7
8	Croatia	82.4
9	Poland	82.1
10	Czechia	81.9
11	United Kingdom	81.9
12	Slovenia	81.2
13	Latvia	81.2
14	Spain	81.0
15	Iceland	80.8
16	Slovak Republic	80.8
17	Estonia	80.8
18	Belgium	80.7
19	Japan	80.7
20	Portugal	80.6
21	Hungary	80.4
22	Italy	80.3

146	Zambia	54.8
147	Nigeria	54.7
148	Comoros	54.7
149	Djibouti	54.3
150	Burkina Faso	53.8
151	Mozambique	53.7
152	Papua New Guinea	53.4
153	Guinea-Bissau	53.1
154	Congo, Republic	52.8
155	Angola	52.8
156	Haiti	52.5
157	Liberia	52.5
158	Madagascar	51.0
159	Niger	50.3
160	Afghanistan	49.1
161	Sudan	49.1
162	Congo, Dem. Rep.	48.2
163	Yemen, Republic	47.7
164	Somalia	46.1
165	Chad	46.0
166	Central African Republic	45.2
167	South Sudan	41.6

Figure 5: The 2025 SDG Index Ranks and scores from [5] first 22 countries (left) and last 22 countries (right)

Countries that started with higher SDG baselines in 2015 have generally progressed more slowly than those with lower baselines, although results vary across regions and country groupings. European and mostly Northen European countries persist at the top of this ranking. At the bottom of the ranking are found countries with SDG Index scores below 50, and they're usually characterized by challenging modernization because of conflicts or political and socio-economical instabilities.

According to the "Financing Sustainable Development to 2030 and Mid-Century. Sustainable Development Report 2025", based on the rate of progress since they were adopted by the international community in 2015, none of the 17 SDGs will be achieved by 2030, with SDGs 2,11,14,15,16 particularly out of track.

Figure 6: World SDG Dashboard 2025 from [5]

2.2 THE ITALIAN SITUATION

As seen in Figure 5: The 2025 SDG Index Ranks and scores from [5] first 22 countries (left) and last 22 countries (right) Italy is at the 22nd place in the ranking with a score of 80,3.

What emerges from "Financing Sustainable Development to 2030 and Mid-Century. Sustainable Development Report 2025" [5] is that the goals that present the worst performance are 12 and 14 while the goal that has been almost achieved is the number 1.

Figure 7: 2025 SDG dashboards for Italy (levels and trends). Source [5]

By taking a closer look to each target, we see how the progress trend goes for each of them. Positive indicators are recorded in most of the targets for SGDs:

- 1 (No poverty)

- 3 (Good Health and Well-Being)
- 9 (Industry, Innovation and Infrastructure)

Eurostat - the statistical office of the European Union – has created a tool that compares each European country's SDG points. From this tool another interesting data is highlighted: compared to the European average, Italy worst status are shown for SDG 17, with -36,14% below EU average, and SDG 8, with -32,24% below EU average.

Inside Italy, disparities are persistent and polarized between North-Centre regions and Southern ones. In the next Figure the values of the measures are shown by region with level zero representing the country's average, in red worse values and in green better ones.

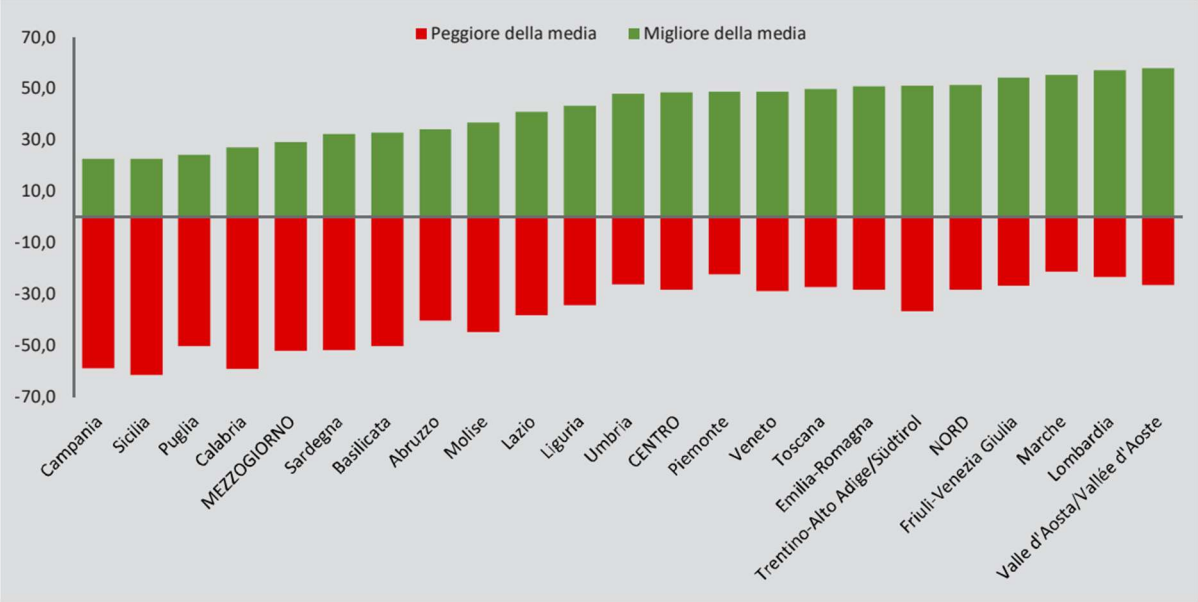


Figure 8: better and worse measures compared to Italian average by region - last available year (in percentage). Source [6]

According to Istat's report *"SDGS 2025. Informazioni statistiche per l'Agenda 2030 in Italia"*, an assessment of statistical indicators compared with the national average highlights the following:

- Northern Italy records 51.2% positive measures
- Central Italy records 48.4% positive measures
- Southern Italy records 52.2% negative measures

The major critical issues are found in the Goals:

- 8 (work and economic growth) ,10 (reduced inequalities), 1 (no poverty), 4 (quality education) for southern Italy.
- 2 (zero hunger),14 (life below water),12 (responsible consumption and production) for northern Italy.

2.3 THE ASSESSMENT METHODOLOGY

The global indicator framework for the Sustainable Development Goals (SDGs) was developed by the Inter-Agency and Expert Group on SDG Indicators (IAEG-SDGs) and endorsed at the 48th session of the United Nations Statistical Commission in March 2017. It was subsequently adopted by the UN General Assembly on 6th July 2017 through the Resolution on the Work of the Statistical Commission pertaining to the 2030 Agenda for Sustainable Development. While this framework defines a common set of global indicators, it is designed to be complemented by regional and national indicators developed by individual Member States.

The global indicator framework includes 234 unique indicators, even though the total number of indicators listed in the global indicator framework of SDG indicators is 251because thirteen of them repeat under two or three different targets. The indicators were classified according to three levels (Tier I, II, III).

To monitor progress, the SDG Index was introduced as an annual measure of advancement towards the 17 SDGs. The Index provides each UN Member State with a country-level score and ranking based on a set of specific, measurable indicators that track performance across the SDGs. These data are compiled annually in the Sustainable Development Report, which also produces SDG dashboards to visualize results for all 193 Member States.

The most recent SDG Index (2025) incorporates 126 indicators: 102 drawn from the global framework and 24 additional indicators tailored to the OECD country dashboards. The Index offers a comprehensive assessment of the “distance to target,” with scores presented on a 0–100 scale. A score of 100 signifies full achievement of all SDGs, while the gap between a country’s score and 100 reflects the remaining percentage points required to reach optimal performance. Countries are ranked according to their overall scores, which summarize total progress across all 17 Goals.

To safeguard comparability and reduce bias from missing data, only countries with less than 20% missing data are assigned an SDG Index score and ranking.

The SDG Index builds on a peer-reviewed, statistically audited, and transparent methodology, refined through online consultations. Feedback was collected from more than 50 organizations—including several National Statistical Offices (NSOs)—as well as 40 UN Member States, ensuring broad input and legitimacy.

To ensure cross-country comparability, the *Sustainable Development Report* does not incorporate estimates submitted directly by national statistical offices. Instead, it relies on the standardized processes established by international organizations to guarantee consistency. Whenever possible, the Report uses official SDG indicators endorsed by the UN Statistical Commission. In cases of data gaps or insufficient availability, it supplements with a combination of official and non-official data sources. Approximately two-thirds of the data are provided by major international organizations—such as the World Bank, OECD, WHO, FAO, ILO, and UNICEF—which apply extensive and rigorous validation procedures.

2.3.1 Procedure to construct SDG Index

The procedure used to calculate the SDG Index comprises three steps [5]:

1. establish performance thresholds and censor extreme values from the distribution of each indicator;
2. rescale the data to ensure comparability across indicators (normalization);
3. aggregate the indicators within and across SDGs.

The choice of upper and lower bounds for each indicator affects the rescaling and as a consequence the ranking of all countries in the index.

The lower bound is defined at the 2.5th percentile of the distribution while the upper bound is determined according to some pre-established criteria (see decision tree [5]).

The rescaling between 0 and 100 is a linear transformation following the formula [5]:

$$x' = \frac{x - \min(x)}{\max(x) - \mathrm{m}\quad(x)} \times 100$$

These principles treat the SDGs as “stretch targets” and emphasize the indicators where a country is falling behind. To improve their SDG Index score, countries must make progress across all goals, with particular attention to those where they are most distant from achievement.

Finally, the aggregation consists of an arithmetic mean of indicators to obtain the cores for each goal and an average of all 17 goals' scores to calculate the SDG Index score of a country.

2.4 ITALY: THE NATIONAL SUSTAINABLE DEVELOPMENT STRATEGY FOR AGENDA 2030

It is useful to consider how national SDGs can be achieved in a systemic way, and how it is possible to identify actions that take into account the multiple relationships existing between the different dimensions of sustainability. [7] In 2017 Italy adopted the *Strategia Nazionale per lo Sviluppo Sostenibile* – in English "National Sustainable Development Strategy (NSDS)" – as a tool to implement the Agenda 2030.

The NSDS defines a set of sustainable development objectives that are related, but not identical, to the Sustainable Development Goals, and are characterized by the interaction among multiple SDGs.

Also, European Member states are working to define a common framework for addressing and reflecting the challenges of the 2030 Agenda. Thanks to the new European Green Deal and the significant commitments undertaken with the National Recovery and Resilience Plan, sustainability is reaffirmed as a key benchmark for evaluating policies across national, European, and international contexts [8].

In this context of a multilevel governance structure, the NSDS is therefore essential to harmonize and optimize efforts, resources, and potential, while relying on the intensive work already in progress and on the existing system of collaborations.

The NSDS includes all dimensions of sustainability, organized into 6 macro-areas for action: People, Planet, Peace, Prosperity, Partnership (5P) and a section dedicated to the Sustainability Enablers. Each area identifies a system of priorities, delivering strategic goals. [9]

In fact, the Italian Strategy does not directly replicate the 17 SDGs and their respective targets from the 2030 Agenda; rather, it focuses on the interconnections among the SDGs, identifying 15 National Strategic Choices (NSCs), which are further articulated into 55 National Strategic Objectives (NSOs). The Partnership area is considered as an "external dimension".

The NSC were developed by the ministry with consultation of all national public research institutes - CNR, ISPRA, ENEA, ISTAT – as well as 217organizations, essentially Universities, or other relevant research centres and NGOs.

Table 1: SDGs involved in each Strategic Choice

People Strategic choices	SDGs
FIGHT POVERTY AND SOCIAL EXCLUSION, ELIMINATING TERRITORIAL GAPS	
GUARANTEE THE CONDITIONS FOR THE DEVELOPMENT OF HUMAN POTENTIAL	
PROMOTE HEALTH AND WELLBEING	

Planet Strategic choices	SDGs
HALT THE LOSS OF BIODIVERSITY	
ENSURE THE SUSTAINABLE MANAGEMENT OF NATURAL RESOURCES	
CREATE RESILIENT COMMUNITIES AND TERRITORIES, PROTECT LANDSCAPES AND CULTURAL HERITAGE	

Prosperity Strategic choices	SDGs
PROMOTE A SUSTAINABLE ECONOMIC WELLBEING	
FUND AND PROMOTE SUSTAINABLE RESEARCH AND INNOVATION	
ENSURE FULL EMPLOYMENT AND HIGH QUALITY TRAINING	
ENSURE SUSTAINABLE PRODUCTION AND CONSUMPTION PATTERNS	
PROMOTE SUSTAINABILITY AND SECURITY OF TRANSPORT AND MOBILITY	
DECARBONIZE THE ECONOMY	

Peace Strategic choices	SDGs
PROMOTE A NON-VIOLENT, INCLUSIVE AND RESPECTFULL OF HUMAN RIGHTS SOCIETY	
END DISCRIMINATION IN ALL ITS FORMS	
ENSURE LEGALITY AND JUSTICE	

Partnership Spheres of action	SDGs
GOVERNANCE, RIGHTS AND COMBAT INEQUALITIES	
MIGRATION AND DEVELOPMENT	
HEALTH	
EDUCATION	
SUSTAINABLE AGRICULTURE AND FOOD SECURITY	

ENVIRONMENT, CLIMATE CHANGE AND ENERGY FOR DEVELOPMENT	
PRESERVATION OF CULTURAL AND NATURAL HERITAGE	
THE PRIVATE SECTOR	

The NSDS is object of a periodic review and updated every three years, involving all actors, institutional and not. The strategy can be seen as an analysis of the interrelations between objectives, targets and national quantitative indicators, that can help to consider synergies and trade-offs between adopted policy measures and to render explicit any "reinforcement or balancing" actions between thematic areas and interconnected issues. [7]

2.4.1 NSDS framework and indicators

Article 34 of Legislative Decree 152/2006 provides for the preparation of annual monitoring reports the National Strategy for Sustainable Development. The same article establishes the connection between sustainability strategies at different territorial levels and specifies that regional strategies must ensure the assessment of their contribution to achieving national sustainability objectives.

Therefore, it is necessary to have an integrated monitoring system for the NSDS, through the selection of a common set of indicators scalable at the territorial level, which form the basis for assessing:

- the contribution of territories to the implementation of the NSDS;
- the support provided by national policies, such as the National Recovery and Resilience Plan (PNRR) or cohesion policies, to the challenge of sustainable development and the achievement of the 2030 Agenda goals.

The Italian statistical system, in coordination with the European system, has made a major effort to ensure the timely availability of data and indicators aligned with those developed by the Inter-Agency and Expert Group on Sustainable Development Goal Indicators (IAEG-SDGs).

As already seen, the IAEG-SDGs has developed 234 to monitor all the SDGs. In the NSDS framework there are in total 55 indicators of first level, produced by a "Working Group for the Definition of Indicators for the National Strategy for Sustainable Development" composed by the Ministry of Foreign Affairs and International Cooperation (MAECI), Ministry of Economy and Finance (MEF), Presidency of the Council of Ministers, Italian National Institute of Statistics (ISTAT) and the Italian Institute for Environmental Protection and Research (ISPRA) [8] (entities belonging to the National Statistical System (SISTAN)).

The same Working Group also developed a set of 89 second-level indicators for monitoring the National Strategic Objectives.

While the first-level indicators are used for the integrated monitoring of the NSDS and are analyzed in its annual Report on the State of Implementation, the second-level indicators will serve for further in-depth analysis.

Most of the indicators used (51 out of 55) are available and described annually in the *"SDGs Report: Statistical Information for the 2030 Agenda in Italy"* by ISTAT, which in turn is aligned with the UN-IAEG-SDGs indicators. Another important source was the 2023 BES Report *"Fair and Sustainable Well-being in Italy"* also by ISTAT.

3 SCIENCE, TECHNOLOGY AND INNOVATION ROLE IN ADVANCING THE SUSTAINABLE DEVELOPMENT GOALS

3.1 INNOVATION AND SUSTAINABLE INNOVATION

The OECD definition of innovation states: An innovation is a new or improved product or process (or combination thereof) that differs significantly from the unit's previous products or processes and that has been made available to potential users (product) or brought into use by the unit (process).

Both traditional and sustainable innovation involve developing new products, services, or processes. Innovation is vital for a company's survival and growth. Firms that don't innovate fall behind their competitors and ultimately go out of business [10]. However, sustainable innovation goes further by intentionally seeking to "meet the needs of present generations without compromising the ability of future generations to meet their own needs."

In most highly industrialized countries, current lifestyles and business models are excessively resource-intensive, environmentally damaging, and socially as well as ecologically unsustainable. Continuing along this path is likely to lead to significant challenges. Therefore, innovation for sustainability has become essential to address the complex and rapidly evolving challenges driving today's global crisis. Sustainable innovations aim to advance sustainability goals by improving the environmental footprint of existing lifestyles, business practices, and consumption patterns [11], innovating in social and institutional structures [12].

In fact, three core features set sustainable innovation apart [10]:

- Sustainable innovations contribute to sustainable businesses - requiring businesses to actively incorporate issues such as human rights, and climate change into their innovation processes, thinking long term beyond seeking immediate profits.
- Sustainable innovations require systems thinking - when companies do not merely focus on their own organization and instead, they look more broadly to the whole system of which they are part understanding of how their actions affect other organizations and vice versa.

- Sustainable innovations must be embedded into firm's culture - sustainable innovations are likely to be more successful when they are deeply embedded in the firm's culture.

This approach requires businesses to actively address global challenges such as those outlined in the Agenda 2030 and United Nations Sustainable Development Goals (SDGs). Companies that embrace sustainable innovation think long-term, aligning their strategies with consumer expectations for fair labour practices, environmentally responsible operations, and positive community impact. Sustainable innovation is often disruptive, as it can lead to new business models, improved processes, more efficient resource use, waste and cost reduction, and the creation of entirely new market segments. In organizations where sustainability is not embedded in the corporate culture, the focus on short-term profits can hold back sustainability-driven ideas before they have the chance to mature. Moreover, sustainable innovation is inherently collaborative and interdisciplinary, transforming the traditional linear "value chain" into a dynamic "value web." This broader perspective encourages companies to consider how their innovations affect not only shareholders but also stakeholders, the environment, and society as a whole [13].

In addition, according to C. L. Vera et al., 2025 [14]: "the post-2020 global scenario – marked by the COVID-19 crisis, digital acceleration and growing geopolitical and economic instability– has catalysed a deep reflection on innovation in terms of resilience, inclusion and ecological restoration. This has led to a growing academic interest in studying the intersection between innovation, circular economy and SDGs, by exploring how different forms of innovation can contribute to sustainability transitions." For this reason, companies that care about sustainability are also more resilient compared to their competitors.

Sustainable innovation is not limited to the creation of new products or services. Companies can also innovate sustainably by transforming their existing processes, even when offering the same products or services.

Achieving sustainable innovation within an organization takes time, commitment, and effort. Three categories or aspects of a company can be innovated sustainably [10]:

- Operational optimization or "*do the same things better*", meaning that without changing their model they reduce their negative environmental and social impacts ("eco-efficiency").

- Organizational transformation or "*doing good by doing new things*" meaning that companies may see sustainability as a business opportunity by creating new products and services that serve societal needs and/or benefit the environment.
- Systems building or "*do good by doing new things with others*" meaning that they extend their thinking beyond the boundaries of the organization to include partners in previously unrelated industries as well as marginalized actors. This creates the greatest change.

It is worth noting that the terms eco-efficiency or eco-innovations are different from sustainable innovation. In fact, the firsts consider environmental burdens while the second is broader to the social and ethical dimensions [12].

However, sustainable practices involving reduced and fairer resource consumption lack of sufficient demand, diffusion and market acceptance. In the established economic, industrial and technological development organisations, innovations are designed to be used to respond in a market-compliant way to corresponding regulations and changes in demand. "Radical" innovations, involving high costs and a high risk of failure are avoided [11].

By contrast, radical innovations driven by sustainability often emerge from industry newcomers or pioneering actors who deliberately seek to promote sustainable change. These innovators challenge existing development models, viewed as environmentally or socially unsustainable, by creating novel and alternative approaches that offer more responsible and resilient solutions.

In the study by Kropp the diffusion process of innovation is defined [11]: "innovations take a non-linear course, from their adoption by young, risk-taking, educated groups of "innovators" to their take-up by rather diverse, opinion-leading "early adopters", to their acceptance by the "early majority" influenced by the early adopters, thus reaching a "critical mass" (Rogers 2003: 343), to their later establishment among the more sceptical "late majority" and, finally, the older "laggards" (Rogers 2003: 282ff.)."

As such, the priority is to understand the conditions that allow sustainable innovations to spread from small "green" pioneer groups into the mainstream industrial system, influencing established markets, business practices, knowledge, consumer habits, and attitudes toward the environment [11].

Concerning the barriers which can influence sustainable innovation, there are different factors affecting both the sustainable production and sustainable consumption innovation [12]:

- lack of available technology or performance capabilities.

- high research costs, difficulty predicting future liability, effects on competitiveness, lack of economies of scale and limited market incentives or recognition for environmentally friendly behaviour.
- strict product requirements and risk of losing customers if product characteristics change.
- a lack of co-operation among different functions within the firm, a reluctance to change operating methods or a lack of education and training of employees.

3.2 INNOVATION AS DRIVER FOR SDGS

When going beyond these barriers, innovation is a key driver in achieving and advancing the Sustainable Development Goals (SDGs). However, the complexity of these goals demands transformational solutions that extend beyond innovation alone, making an integrated approach that combines Science, Technology, and Innovation (STI) essential [15].

Together, STI provides a comprehensive approach in which science generates new knowledge, technology converts that knowledge into practical tools, and innovation leverages these tools to create solutions, improve systems, and address societal challenges. In this sense, technology acts as the bridge linking science to innovation.

Dzhunushalieva and Teuber (2024) identified 31 out of 169 SDG's targets that mentioned at least one innovation-related term. The term "innovation" was itself mentioned in SDG 9 and targets 8.2, 8.3, 9.5 and 9.b. The term "STI" was observed in SDGs 17.6 and 17.8, and the terms "research" and "science" were repeatedly mentioned, with 14 and 9 occurrences respectively. However, the most frequently used term was "technology" (including ICT), which appeared 33 times. Technology was found to be relevant across four dimensions of the 5Ps: People, Prosperity, Planet and Partnership. [15]

Also, thanks to this study, the text-mining technique identified four clusters relevant to understanding the role of innovation in achieving the SDGs. The first cluster embodies the vital task of fostering sustainable development. The key innovations most closely connected with achieving the SDGs include social innovation, frugal innovation, open innovation, business model innovation and digital innovation. The second cluster emphasises technological innovation, which sees as the driving force behind economic growth; the third cluster focuses on policies and initiatives that promote innovation and, finally, the fourth cluster indicates that innovation enhances business performance [15].

Innovation generates cross-cutting effects across multiple Sustainable Development Goals, the approach resulting from the combination of STI can be more effective when recognizing the interconnected nature of SDGs.

3.2.1 SDG 9 (Industry, innovation and infrastructure)

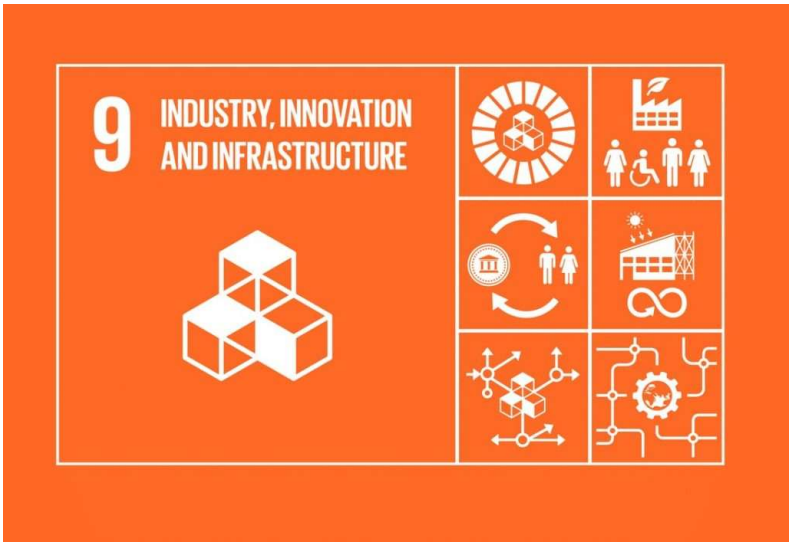


Figure 9: SDG 9 logo

SDG 9—Industry, Innovation, and Infrastructure—is examined in depth in this thesis and serves as the starting point for exploring the role of innovation in advancing the achievement of the Sustainable Development Goals. The analysis begins with an overview of the current state of implementation of SDG 9 and the key challenges within the Italian context and then focuses on its interconnections with other SDGs.

The objective of this goal is to build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation. It comprises 8 targets, each with specific indicators, of which the most relevant to this thesis are:

Table 2: Selected targets with indicators from SDG 9

Target	Indicators
9.2 Promote inclusive and sustainable industrialization and, by 2030, significantly raise industry's share of employment and gross domestic product, in line with national	9.2.1 Manufacturing value added as a proportion of GDP and per capita

circumstances, and double its share in least developed countries.	9.2.2 Manufacturing employment as a proportion of total employment
9.4 By 2030, upgrade infrastructure and retrofit industries to make them sustainable, with increased resource-use efficiency and greater adoption of clean and environmentally sound technologies and industrial processes, with all countries taking action in accordance with their respective capabilities.	9.4.1 CO2 emission per unit of value added
9.5 Enhance scientific research, upgrade the technological capabilities of industrial sectors in all countries, in particular developing countries, including, by 2030, encouraging innovation and substantially increasing the number of research and development workers per 1 million people and public and private research and development spending.	9.5.1 Research and development expenditure as a proportion of GDP 9.5.2 Researchers (in full-time equivalent) per million inhabitants
9.b Support domestic technology development, research and innovation in developing countries, including by ensuring a conducive policy environment for, inter alia, industrial diversification and value addition to commodities.	9.b.1 Proportion of medium and high-tech industry value added in total value added

3.2.2 Advancement of SDG 9 Worldwide and Italy's Standing

SDG 9 appears to be one of the most on track targets as, since 2015, the global research workforce has grown annually by 4.3 per cent, from 1,137 to 1,420 researchers per million people in 2022.

Eastern and South-Eastern Asia in the first place increased their R&D workforce with a 5.3 per cent growth rate, followed by Europe and Northern America that have the highest researcher densities, increasing from 3,513 to 4,254 per million inhabitants. Sub-Saharan Africa remained stagnant highlighting persistent disparities in research capacity with 91 researchers per million.

On the investments level, from 2015 to 2022, despite COVID-19 disruptions, research investments grew by 5.1 per cent annually [4]. The share of the global GDP invested in R&D climbed from 1.72 to 1.95 per cent during this period, driven largely by Europe and Northern America as well as Eastern and South-Eastern Asia. However, Latin America and the Caribbean, as well as Central and Southern Asia, didn't see any investments increase.

Disparities are persistent and for this reason stronger policies for developing countries and their sustainable innovation are needed.

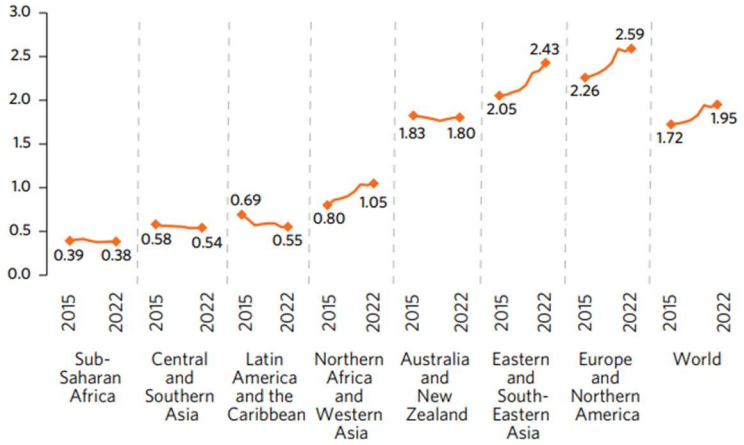


Figure 10: Research and development global expenditure as a proportion of GDP, 2015-2022 (percentage). Source [4]

In Italy during the last decade, many indicators for goal 9 have been improving, such as emissions, digital infrastructures, e-commerce and companies' innovation, while some other measures have worsened like research intensity and number of people employed in the ICT sector.

Research intensity, which is calculated as the ratio between the expenditure in R&D and the national GDP, has increased in all Italian regions since 2012, as shown in Figure 11, but it has also decreased to 1.37% from 1.43% in 2021, placing it among the lowest levels in the EU27 [6].

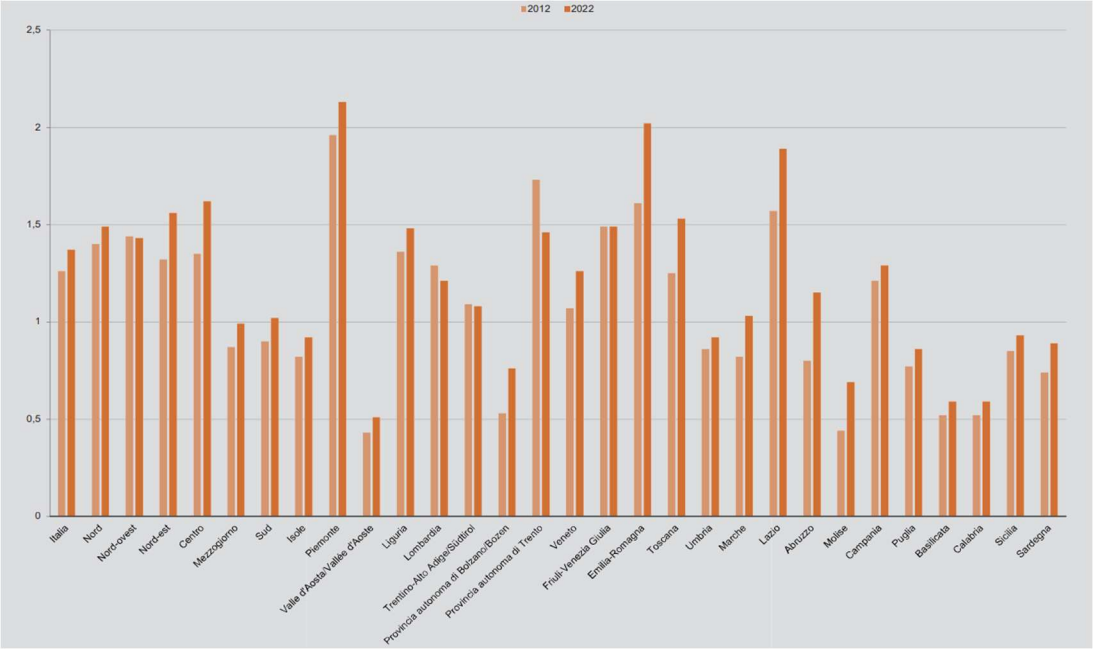


Figure 11: Research intensity by region and geographical area - years 2012 and 2022 (in percentage). Source: Istat

Also, the number of researchers has grown, from about 18 per 10,000 inhabitants in 2012 to 28,3 in 2022 [6]. This positive trend has been registered for all regions, leading the autonomous Province of Trento and the region Emilia-Romagna.

Deep gender disparities have to be mentioned as in 2022, male researchers reached an incidence of 36.8 per 10,000 inhabitants, significantly higher than that of women, who stood at 20.1 [6].

As previously mentioned, a negative trend arises for workers employed in specialized ICT roles. Between 2018 and 2024, the indicator decreased overall by 0.5 percentage points, with sharper declines in the North despite the increasing digitalization of businesses [6].

On the innovation front, between 2020 and 2022, the share of enterprises with 10 or more employees that introduced at least one innovation with positive environmental effects rose from 37% to 40.1% [6]. Among the economic sectors with greater dynamism there are services (excluding transport) and construction, while the manufacturing sector shows a slight setback.

Finally, also the carbon intensity evaluation falls under SDG 9. We see that in Italy between 2022 and 2023 the total carbon intensity of different economic activities has fallen, recording an overall decline of 8%: from 143.7 to 132.2 tonnes per million euros [6].

Nevertheless, in the last decade some sectors such as the mining industry, together with agriculture, forestry, and fishing, increased emission intensity by 121.9% and 7.6% [6] respectively, going against the trend observed in the other sectors.

3.3 INTERLINKAGES AMONG SDGS

Since the 2030 Agenda was conceived as an integrated and indivisible framework, the Sustainable Development Goals (SDGs) are inherently interlinked and interdependent. SDG interlinkages therefore refer to the complex network of relationships connecting the goals, their targets, and indicators. These relationships may be positive, negative, or mixed in nature, and can occur across different geographical and temporal scales, generating varying levels of impact.

SDG interlinkages illustrate how actions undertaken to advance one goal can influence progress toward others, either reinforcing synergies or creating trade-offs. Identifying and understanding these interactions is essential for effectively implementing the 2030 Agenda, as it helps maximize co-benefits while minimizing the risk of unintended negative effects on other SDGs.

Relationship between different goals may be of different kinds, as illustrated in the following table from K. B. Mantlana and M. A. Maoela.

Table 3: Definition of terms describing interlinkages [16]

Definition of terms
Context-independent: The achievement of an SDG target invariably contributes to the achievement of another SDG target.
Context-dependent: The achievement of an SDG target does not activate the achievement of other targets.
Co-benefit or *synergy:* there are added benefits through the implementation of an SDG target that supports the fulfilment of other SDGs.
Trade-off: there is a compromise or tension that may happen between a first SDG target and another SDG target while implementing one.
Neutral: an SDG target has no influence on the fulfilment of the other SDG target.
Prerequisite: Progress in fulfilling an SDG target first needs to happen (is needed) to fulfil the other SDG target.

Nonessential: Progress in fulfilling an SDG target is not necessary to fulfil the other SDG target.

Climate change (SDG 13) has many synergistic relationships with other goals, such as clean and affordable energy (SDG 7), good health and well-being (SDG 3) and responsible consumption and production (SDG 12). Conversely, fighting climate change (SDG 13) in the EU appears to be negatively associated with ending poverty (SDG 1) and hunger (SDG 2). Additionally, indicators on partnerships for the goals (SDG 17) show quite many trade-offs with other goals. Kostetckaia (2022) suggests that trade-offs have a bigger influence on the pace of countries' progress towards the goals than synergies. In order to achieve the SDGs by 2030, it is thus crucial to not only exploit synergies between the goals but also to overcome trade-offs. [17]

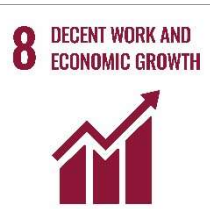
In particular, the SDG pairs 9–11 and 11–13 constitute large trade-offs. This finding emphasizes the need to invest in research to foster innovations that can make our cities and communities more sustainable, as well as climate friendly. [18]

The Italian National Sustainable Development Strategy previously pictured, defines some interlinkages inside the strategic choices. Table 4 aims to highlight how each SDG can contribute in a cross-cutting way to the 5Ps proposed by the NSDS.

Table 4: Contribution and occurrence of each SDG to the 5Ps of the NSDS.

SDGs	5Ps and strategic choices involved	Occurrence
	**People** • FIGHT POVERTY AND SOCIAL EXCLUSION ELIMINATING TERRITORIAL GAPS **Partnership** • SUSTAINABLE AGRICULTURE AND FOOD SECURITY	2
	**People** • FIGHT POVERTY AND SOCIAL EXCLUSION, ELIMINATING TERRITORIAL GAPS • PROMOTE HEALTH AND WELLBEING **Planet** • HALT THE LOSS OF BIODIVERSITY • ENSURE THE SUSTAINABLE MANAGEMENT OF NATURAL RESOURCES	5

	Partnership • SUSTAINABLE AGRICULTURE AND FOOD SECURITY	
	**People** • PROMOTE HEALTH AND WELLBEING Partnership • Health	2
	**People** • GUARANTEE THE CONDITIONS FOR THE DEVELOPMENT OF HUMAN POTENTIAL **Prosperity** • FUND AND PROMOTE SUSTAINABLE RESEARCH AND INNOVATION • ENSURE FULL EMPLOYMENT AND HIGH-QUALITY TRAINING **Peace** • PROMOTE A NON-VIOLENT, INCLUSIVE AND RESPECTFULL OF HUMAN RIGHTS SOCIETY • END DISCRIMINATION IN ALL ITS FORMS **Partnership** • Education • Natural heritage	7
	**Prosperity** • PROMOTE A SUSTAINABLE ECONOMIC WELLBEING **Peace** • PROMOTE A NON-VIOLENT, INCLUSIVE AND RESPECTFULL OF HUMAN RIGHTS SOCIETY • END DISCRIMINATION IN ALL ITS FORMS • ENSURE LEGALITY AND JUSTICE **Partnership** • GOVERNANCE, RIGHTS AND COMBAT INEQUALITIES	5

	**People** • FIGHT POVERTY AND SOCIAL EXCLUSION ELIMINATING TERRITORIAL GAPS **Planet** • ENSURE THE SUSTAINABLE MANAGEMENT OF NATURAL RESOURCES **Prosperity** • ENSURE SUSTAINABLE PRODUCTION AND CONSUMPTION PATTERNS **Partnership** • HEALTH • SUSTAINABLE AGRICULTURE AND FOOD SECURITY	
	**Prosperity** • PROMOTE SUSTAINABILITY AND SECURITY OF TRANSPORT AND MOBILITY • DECARBONIZE THE ECONOMY **Partnership** • ENVIRONMENT, CLIMATE CHANGE AND ENERGY FOR DEVELOPMENT • THE PRIVATE SECTOR	4
	**People** • GUARANTEE THE CONDITIONS FOR THE DEVELOPMENT OF HUMAN POTENTIAL **Planet** • CREATE RESILIENT COMMUNITIES AND PROTECT LANDSCAPES AND CULTURAL HERITAGE **Prosperity** • PROMOTE A SUSTAINABLE ECONOMIC WELLBEING • ENSURE FULL EMPLOYMENT AND HIGH-QUALITY TRAINING • ENSURE SUSTAINABLE PRODUCTION AND CONSUMPTION PATTERNS **Peace**	10

	• PROMOTE A NON-VIOLENT, INCLUSIVE AND RESPECTFULL OF HUMAN RIGHTS SOCIETY • END DISCRIMINATION IN ALL ITS FORMS **Partnership** • GOVERNANCE, RIGHTS AND COMBAT INEQUALITIES • MIGRATION AND DEVELOPMENT • THE PRIVATE SECTOR	
	**Prosperity** • PROMOTE A SUSTAINABLE ECONOMIC WELLBEING • FUND AND PROMOTE SUSTAINABLE RESEARCH AND INNOVATION • PROMOTE SUSTAINABILITY AND SECURITY OF TRANSPORT AND MOBILITY • DECARBONIZE THE ECONOMY **Partnership** • THE PRIVATE SECTOR	5
	**People** • FIGHT POVERTY AND SOCIAL EXCLUSION, ELIMINATING TERRITORIAL GAPS **Prosperity** • PROMOTE A SUSTAINABLE ECONOMIC WELLBEING • ENSURE SUSTAINABLE PRODUCTION AND CONSUMPTION PATTERNS **Peace** • PROMOTE A NON-VIOLENT, INCLUSIVE AND RESPECTFULL OF HUMAN RIGHTS SOCIETY • END DISCRIMINATION IN ALL ITS FORMS **Partnership** • GOVERNANCE, RIGHTS AND COMBAT INEQUALITIES • MIGRATION AND DEVELOPMENT	7

	**People** • FIGHT POVERTY AND SOCIAL EXCLUSION, ELIMINATING TERRITORIAL GAPS • PROMOTE HEALTH AND WELLBEING **Planet** • ENSURE THE SUSTAINABLE MANAGEMENT OF NATURAL RESOURCES • CREATE RESILIENT COMMUNITIES AND PROTECT LANDSCAPES AND CULTURAL HERITAGE **Prosperity** • ENSURE SUSTAINABLE PRODUCTION AND CONSUMPTION PATTERNS • PROMOTE SUSTAINABILITY AND SECURITY OF TRANSPORT AND MOBILITY **Peace** • ENSURE LEGALITY AND JUSTICE **Partnership** • ENVIRONMENT, CLIMATE CHANGE AND ENERGY FOR DEVELOPMENT • NATURAL HERITAGE	9
	**Planet** • ENSURE THE SUSTAINABLE MANAGEMENT OF NATURAL RESOURCES **Partnership** • SUSTAINABLE AGRICULTURE AND FOOD SECURITY • ENVIRONMENT, CLIMATE CHANGE AND ENERGY FOR DEVELOPMENT	3
	**Planet** • ENSURE THE SUSTAINABLE MANAGEMENT OF NATURAL RESOURCES **Prosperity** • ENSURE SUSTAINABLE PRODUCTION AND CONSUMPTION PATTERNS • DECARBONIZE THE ECONOMY	4

	Partnership • ENVIRONMENT, CLIMATE CHANGE AND ENERGY FOR DEVELOPMENT	
	**Planet** • HALT THE LOSS OF BIODIVERSITY • ENSURE THE SUSTAINABLE MANAGEMENT OF NATURAL RESOURCES **Partnership** • ENVIRONMENT, CLIMATE CHANGE AND ENERGY FOR DEVELOPMENT	3
	**Planet** • HALT THE LOSS OF BIODIVERSITY • ENSURE THE SUSTAINABLE MANAGEMENT OF NATURAL RESOURCES • CREATE RESILIENT COMMUNITIES AND PROTECT LANDSCAPES AND CULTURAL HERITAGE **Prosperity** • ENSURE SUSTAINABLE PRODUCTION AND CONSUMPTION PATTERNS **Partnership** • ENVIRONMENT, CLIMATE CHANGE AND ENERGY FOR DEVELOPMENT • NATURAL HERITAGE	6
	**People** • FIGHT POVERTY AND SOCIAL EXCLUSION, ELIMINATING TERRITORIAL GAPS • PROMOTE HEALTH AND WELLBEING **Peace** • PROMOTE A NON-VIOLENT, INCLUSIVE AND RESPECTFULL OF HUMAN RIGHTS SOCIETY • END DISCRIMINATION IN ALL ITS FORMS • ENSURE LEGALITY AND JUSTICE **Partnership** • GOVERNANCE, RIGHTS AND COMBAT INEQUALITIES	6

	**Peace** • PROMOTE A NON-VIOLENT, INCLUSIVE AND RESPECTFULL OF HUMAN RIGHTS SOCIETY • END DISCRIMINATION IN ALL ITS FORMS • ENSURE LEGALITY AND JUSTICE	3

A real-world example of SDG interlinkages is described in the literature (F. Cappellaro et al.[19]), which shows how innovative interventions in the energy sector, in this case Renewable Energy Communities (RECs), can simultaneously contribute to multiple SDGs through systemic interactions among technological, social, and governance dimensions. Strong interconnections emerge among SDG 7 (Affordable and Clean Energy), SDG 11 (Sustainable Cities and Communities), SDG 12 (Responsible Consumption and Production), and SDG 13 (Climate Action). These goals are not pursued independently but become mutually reinforcing through the social, technological, and institutional processes activated by the creation of energy communities.

RECs promote the adoption of renewable energy and improvements in energy efficiency, thereby advancing SDG 7 while addressing energy poverty. At the same time, they support SDG 11 by fostering participatory governance, citizen engagement, and decentralized urban energy systems, contributing to more inclusive and resilient communities. Through tools such as smart meters, monitoring systems, and digital platforms, energy communities also encourage more responsible consumption patterns, supporting SDG 12. Collectively, these dynamics contribute to SDG 13 by reducing emissions and increasing awareness of climate impacts.

Moreover, the paper highlights that these interconnections may generate indirect benefits for additional SDGs, including SDG 1 (No Poverty), SDG 8 (Decent Work and Economic Growth), SDG 9 (Industry, Innovation and Infrastructure), and SDG 10 (Reduced Inequalities), through local economic development, technological innovation, and increased social inclusion promoted by community-based energy initiatives.

3.3.1 Interlinkages in support of innovation

The most important role is represented by the indicators associated with scientific research, technological development and innovation (target 9.5), since these represent the tools through which to achieve many of the objectives of sustainable development: from the improvement of morbidity and mortality to the lengthening of the life expectancy thanks to the results of medical research (Goal 3), the expansion of technological innovation in agriculture (Goal 2), energy (Goal

7) and marine life (Goal 14) to the promotion of cooperation for capacity building and extension of scientific and technological knowledge, particularly in developing countries (Goal 12 and 17) [7].

The adoption of technologies and production processes that are less harmful to the environment, referred to by the 9.4 target, impacts, in terms of CO2 emissions (indicator 9.4.2), on the indicators concerning air quality (Goal 11) and the climate change (Goal 13). The support and strengthening of the industry (target 9.2), an important source of income and work, is functional to combat poverty (Goal 1) and to economic growth and employment (Goal 8). [7]

Figure 12: Statistical indicators for SDGs monitoring, Innovation, research, infrastructure indicators and interlinkages according to UN-IAEG-SDGs [7]

Notably, SDG 9 is characterized by an abundance of interconnections.

Mantlana and Maoela (2020) evaluated the interlinkages between SDG 9 and other 6 SDGs relating to social inclusion (SDG 2 and 11), environmental sustainability (SDG 6, 13, and 15), and energy (SDG 7) [16]:

The targets of SDG 9 showed interlinkages with all SDGs that were evaluated. The analysis showed that co-benefits were the most dominant interaction (79%), indicating compatibilities between industry, infrastructure, and innovation and the food–water–climate–energy–land use nexus. The largest contribution (68%) came from the prerequisite context independent

relationships. This means that progress in fulfilling SDG 9 target first needs to happen to fulfil the other SDG target and the achievement of SDG 9 target invariably contributes to the achievement of another SDG target.

Results showed few neutral interactions (13%), where an SDG 9 target has no influence on the fulfilment of the other SDG target, and even fewer trade-off interactions (8%), for which there is a compromise or tension that may happen between an SDG 9 target and another SDG target while implementing an SDG 9 target.

Three SDG 9 targets (9.5, 9.b, and 9.c) were the most interlinked with all other targets. The same three targets also showed the largest number of positive relationships. Target 9.2 showed the highest number of trade-offs. The targets of SDG 11 showed the highest number of positive interlinkages with the targets of SDG 9; the strongest positive interlinkage was shown by the targets of SDG 9 and those of SDG 7; SDG 2 had the largest number of neutral interlinkages; SDG15 the largest number of the trade-offs. [16]

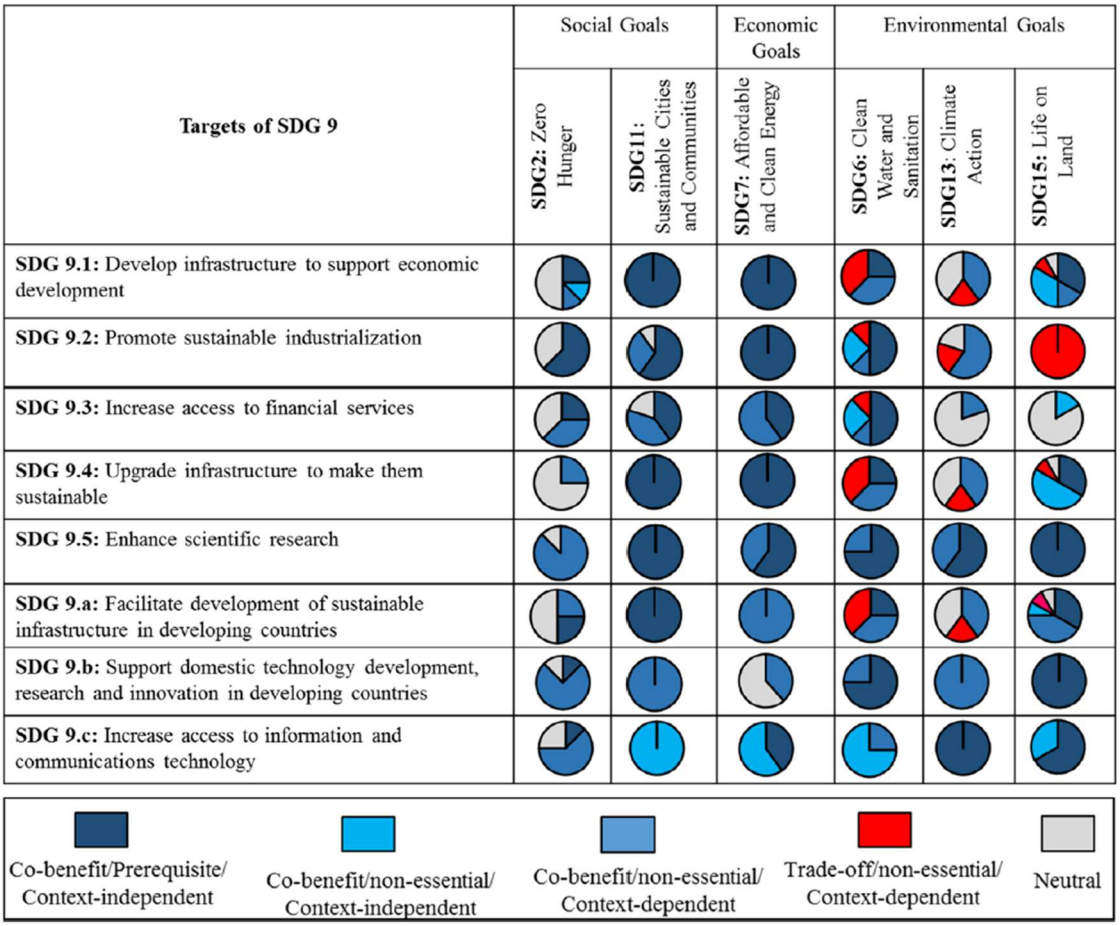


Figure 13: Characterized relationships between SDG 9 targets and SDGs 2,6,7,11,13,15. Each sector of the pie chart represents a particular proportion of targets within SDGs to which a given SDG 9 target interlinks. Source [16].

A further in-depth analysis was conducted by ASviS (Alleanza Italiana per lo Sviluppo Sostenibile) in its 2022 Position Paper [20] developed by the SDG 9 working group. The analysis highlights that innovation is most strongly linked to SDGs 1, 3, 10, and 12, as well as to SDGs 2, 4, 7, and 16. Surprisingly, the SDGs for which the contribution of innovation appears to be weaker are SDG 11 and SDG 17.

3.3.2 KnowSDGs database for interlinkages

Knowledge base for the Sustainable Development Goals is a web platform of the European Commission that provides tools and organises knowledge on policies, indicators, methods and data to support the evidence-based implementation of the SDGs.

Inside this platform, it is found an SDG Interlinkages Tool that contributes to the collective knowledge on the interconnections across SDGs and their implications for real-life policymaking with a well-rounded assessment of the SDG Interlinkages described in the literature. On the one side, the Interlinkages Tool raises awareness of the 2030 Agenda and its interlinked nature. On the other side, in particular, this exercise supports policymakers progressing with the Agenda by understanding interactions across SDGs, in order to prevent negative impacts and build coherent and synergistic policies for sustainable development. [21]

The database is fed by 92 publications found on Scopus and Google Scholar and includes articles, reviews and reports, published from 2015, the year of adoption of the 2030 Agenda. All clearly identifiable interlinkages between a pair of two different SDG goals, targets, or indicators were recorded, together with other information, including the type of methods used to identify interlinkages, the geographical and temporal scales, the sign of interaction (positive, negative, or mixed), the direction of interaction, its strength and description. [21]

On this network we can find the data already summarized at the goal level, or you can go more in detail with the target level. By using this database, it is possible to explore interlinkages by chord diagrams with an overview of synergies and trade-offs.

The following diagrams are taken from KnowSDGs Interlinkages Tool and represent synergies and trade-offs of the selected targets from SDG 9.

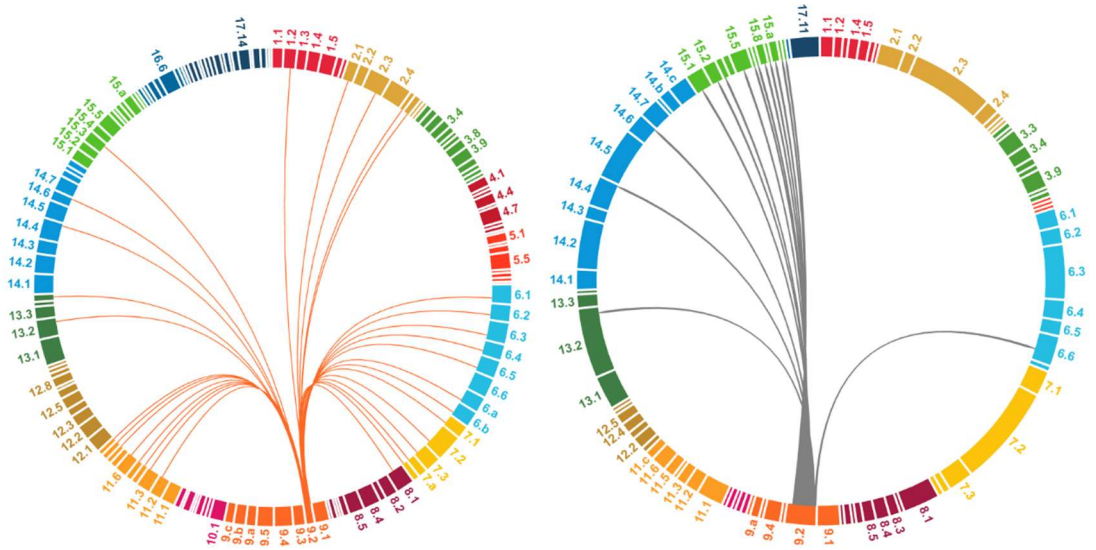


Figure 14: target 9.2 chord diagrams - overview of synergies (left) and trade-offs (right)

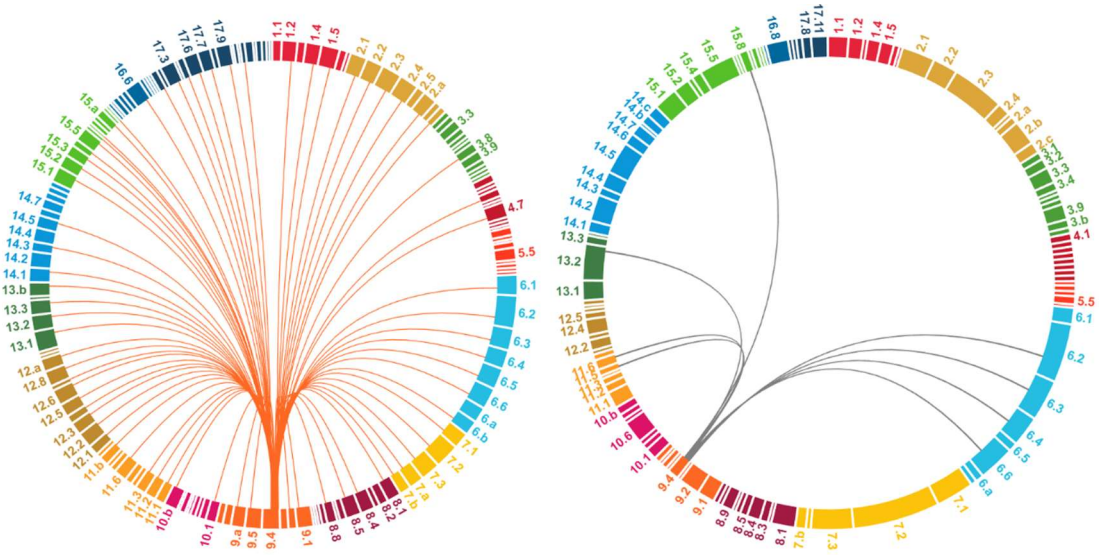


Figure 15: target 9.4 chord diagrams - overview of synergies (left) and trade-offs (right)

Figure 16: target 9.5 chord diagrams - overview of synergies (left) and trade-offs (right)

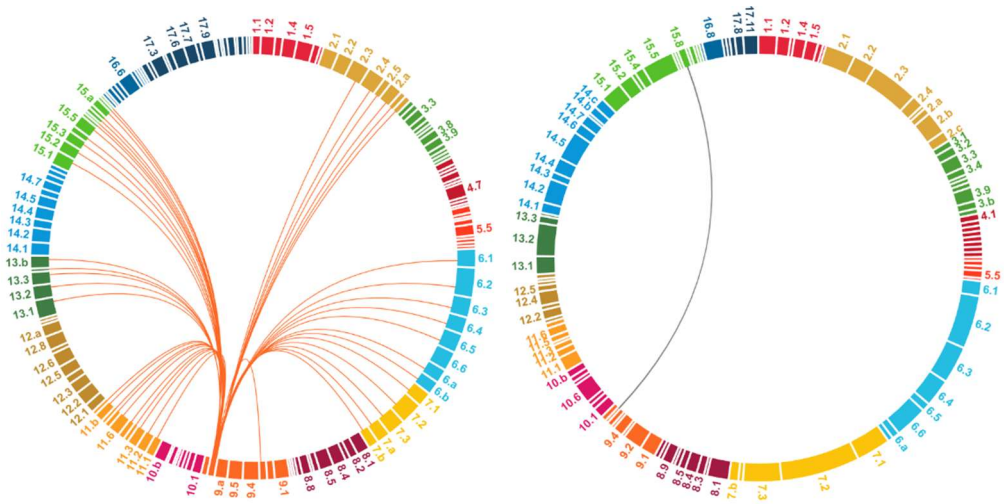


Figure 17: target 9.b chord diagrams - overview of synergies (left) and trade-offs (right)

We can see that the selected targets are highly interlinked with other targets, with 9.4 and 9.5 showing the largest variety of links. The number of synergies registered are visibly more than the number of trade-offs.

The trade-offs emerging are mostly related to SDGs 6,14,15, mainly because of natural resources exploitation and pollution of natural environments.

3.3.3 NSDS Prosperity targets and SDG 9

As already seen, one important aspect of SDG 9 is innovation, and the National Sustainable Development Strategy emphasizes its interlinkages in one of the 5Ps: the “Prosperity” dimension clearly illustrates the interconnections between innovation and several SDGs.

In the “prosperity” area are included the Strategic Choices that support and promote the creation of a new circular economic model, contributing to the minimization of the negative impacts on the environment by closing the loop between production and consumption cycles and by enhancing human full development and a more efficient and responsible use of resources. [9]

Economic, social, and technological progress must address key challenges such as decarbonizing the economy, advancing research and innovation in sustainability, promoting sustainable production and consumption patterns, strengthening professional and vocational training, and fostering sustainable employment.

Table 5: National Strategic Goals for each National Strategic Choice of Prosperity. Source [8]

National Strategic Choices	National Strategic Goals
1. **PROMOTE A SUSTAINABLE ECONOMIC WELLBEING**	**I.1** Ensure the vitality of the productive system **I.2** Guarantee economic well-being and an equitable distribution of income
2. **FUND AND PROMOTE SUSTAINABLE RESEARCH AND INNOVATION**	**II.1** Increase investment in research and development **II.2** Implement the Digital Agenda and strengthen the diffusion of smart networks **II.3** Innovate processes and products and promote technology transfer
3**. ENSURE FULL EMPLOYMENT AND HIGH-QUALITY TRAINING**	**III.1** Ensure accessibility, quality, and continuity in education and training **III.2** Increase sustainable and quality employment
4. **ENSURE SUSTAINABLE PRODUCTION AND CONSUMPTION PATTERNS**	**IV.1** Dematerialize the economy, reduce waste generation, and promote the circular economy **IV.2** Implement ecological tax reform and expand the use of sovereign green bonds **IV.3** Promote social, environmental, and human rights responsibility within public administrations and businesses, including

	through sustainable finance **IV.4** Promote demand for and increase the supply of sustainable tourism **IV.5** Ensure the sustainability of agriculture and the entire forestry supply chain **IV.6** Ensure the sustainability of aquaculture and fisheries across the entire supply chain **IV.7** Promote Italian excellence
5. **PROMOTE SUSTAINABILITY AND SECURITY OF TRANSPORT AND MOBILITY**	**V.1** Ensure sustainable infrastructure **V.2** Promote sustainable mobility for people and goods
6. **DECARBONIZE THE ECONOMY**	**VI.1** Reduce energy consumption and increase energy efficiency **VI.2** Increase the production of energy from renewable sources while avoiding or minimizing impacts on cultural heritage and the landscape **VI.3** Reduce greenhouse gas emissions

INDICATORS AND TARGETS from *"STRATEGIA NAZIONALE PER LO SVILUPPO SOSTENIBILE 2022"*

1. PROMOTE A SUSTAINABLE ECONOMIC WELLBEING

INDICATOR	SOURCE	TARGET VALUE (if present)
10.1.1 Income Inequality (s80/s20)	ISTAT	
10.1.1 Adjusted Gross Disposable Income per Capita	ISTAT	
8.1.1 Annual Growth Rate of Real GDP per Capita	ISTAT	

2. FUND AND PROMOTE SUSTAINABLE RESEARCH AND INNOVATION

INDICATOR	SOURCE	TARGET VALUE (if present)
9.4.1 CO_2 Emission Intensity per Unit of Value Added	ISTAT	
9.5.1 Research Intensity (% of R&D Investment/GDP)	ISTAT	By 2030, in Europe 3% of GDP will be invested in research; by 2030, in Italy 1.57% of GDP will be invested in research.
9.5.2 Researchers (Full-Time Equivalent)	ISTAT	

3. ENSURE FULL EMPLOYMENT AND HIGH-QUALITY TRAINING

INDICATOR	SOURCE	TARGET VALUE (if present)
8.5.2 Employment Rate (Ages 20–64)	ISTAT	By 2030, achieve a 78% employment rate (ages 20–64)
8.6.1 Young People Not in Employment, Education, or Training (NEET)	ISTAT	By 2030, reduce the European rate of NEETs (young people aged 15–29 who are not in employment, education, or training) from 12.6% (2019) to 9%.

4. ENSURE SUSTAINABLE PRODUCTION AND CONSUMPTION PATTERNS

INDICATOR	SOURCE	TARGET VALUE (if present)
12.2.2 Domestic Material Consumption per Unit of GDP	ISTAT	
12.2.2 Domestic Material Consumption per Capita	ISTAT	
12.5.1 Separate Collection of Municipal Waste	ISPRA	

12.5.1 Circular Material Use Rate	ISPRA	By 2030, increase the circular use rate of materials to 30%
2.4.1 Share of Agricultural Area under Organic Farming	MASAF	By 2030, ensure that 25% of agricultural land is dedicated to organic farming

5. PROMOTE SUSTAINABILITY AND SECURITY OF TRANSPORT AND MOBILITY

INDICATOR	SOURCE	TARGET VALUE (if present)
7.1.2 Share of Newly Registered Electric or Hybrid Cars	ISTAT	By 2030, 25% of the market (6 million electric cars)
9.1.2 Freight Transport Volumes by Mode of Transport	ISTAT	By 2030, double the share of freight transported by rail
9.1.2 Passenger Transport Volumes by Mode of Transport	ISTAT	By 2030, double high-speed rail traffic

6. **DECARBONIZE THE ECONOMY**

INDICATOR	SOURCE	TARGET VALUE (if present)
13.2.2 CO_2 and Other Greenhouse Gas Emissions	ISTAT - ISPRA	By 2030, a 51% reduction compared to 1990 levels, corresponding to 256 million tonnes of CO_2 equivalent. To achieve this goal, it is necessary to: • By 2030, reduce emissions in the ETS sector by 62% compared to 2005; • By 2030, reduce emissions in the non-

		ETS sector by 43.7% compared to 2005;
7.2.1 Electricity from Renewable Sources	TERNA S.p.A.	By 2030, ensure that 65% of total national electricity consumption is covered by renewable energy sources;
7.2.1 Share of Energy from Renewable Sources in Gross Final Energy Consumption	GSE	By 2030, achieve a 40.5% reduction in gross final energy consumption through renewable sources;
7.3.1 Energy Intensity	ENEA	By 2030, integrating all planned policies, the national scenario estimates a final energy consumption of about 100 Mtoe

SDG 9 is the core Goal of the "Prosperity" dimension of the Strategy, as it is recurrent in 4 different Strategic choices. The other SDGs referred to under "Prosperity" are largely consistent with those identified as interlinkages with SDG 9 in the previously cited sources; however, they may differ in terms of their relative importance, as reflected by their frequency of occurrence.

According to the previous Table 4 on the occurrence of each SDG to the 5Ps of the NSDS, SDGs presence in "prosperity" are showed in Figure 18.

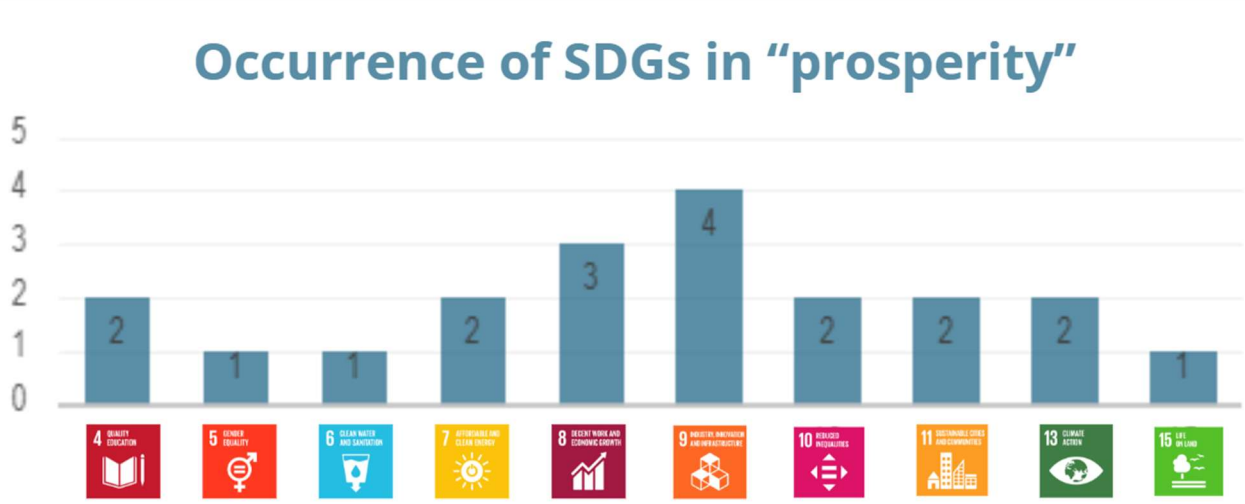


Figure 18: SDGs referred to in the area "prosperity"

More than the half of all SDGs are recalled in this macro area, linking SDG 9 to most SDGs. This again highlights that progress on SDG 9 generates impacts across many other SDGs.

Interestingly, SDG 8 – Decent Work and Economic Growth – is the second most frequently cited goal, which is consistent with the very nature of the “Prosperity” dimension. Once again, this highlights the strong potential connection between innovation and economic growth.

3.4 Conclusion: Interlinkages of SDG 9 with other targets

Overall, SDG 9 functions as a backbone of the sustainable development framework. Strengthening innovation capacity, ensuring inclusive access to technology, and fostering environmentally responsible industrialization are not only essential for achieving SDG 9 itself, but also for unlocking progress across the entire SDG system. Integrated, evidence-based policymaking that accounts for synergies and mitigates trade-offs is therefore crucial to maximize the transformative potential of SDG 9.

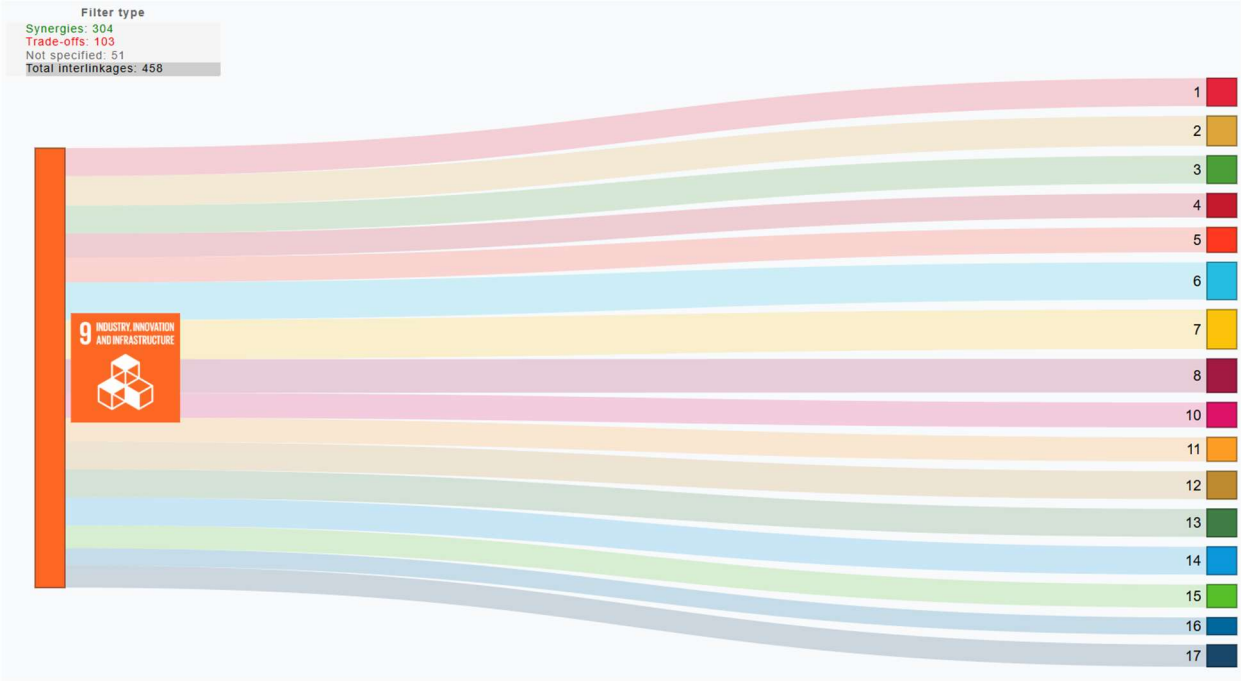


Figure 19 Sankey diagram: overview of interlinkages between selected targets. Line thickness depends on the n° of publications that record the interlinkages existing at goal or target level for that pair of SDGs. From KnowSDGs Interlinkages Tool.

SDG 9 is a highly interconnected goal within the 2030 Agenda. Co-benefits and prerequisite relationships dominate these interlinkages, while trade-offs are relatively limited but still relevant, particularly in areas involving industrial expansion and environmental protection.

The literature shows that analysing interlinkages is a complex task that can be addressed through different methodological approaches. Findings vary substantially, largely depending on the type of publications included in the analysis.

For instance, within the KnowSDGs interlinkages database, many studies focus on projects in developing countries, where challenges such as food security and access to clean water are more prominent than in developed contexts. This scale difference makes comparisons across studies particularly difficult.

According to the *Second Report of the Interlinkages Workstream* (2020) by IAEG-SDG, the strongest interconnections—those involving between four and ten indicators—are associated with SDGs 1, 4, 8, 13, and 17.

Mantlana and Maoela (2020) find that targets 9.5, 9.b, and 9.c are the most interconnected with other targets, exhibiting the highest number of positive relationships. In contrast, target 9.2 shows the greatest number of trade-offs. The strongest positive interlinkages involving SDG 9

targets are observed with SDGs 11, and 7, while SDG 2 displays predominantly neutral interlinkages and SDG 15 present the highest number of trade-offs.

The Position Paper on SDG 9 of 2022 by ASviS links innovation and SDG 1, SDG 3, SDG 10, and SDG 12.

Finally, results from the SDG Interlinkages Tool indicate that most interlinkages involve SDGs 6, 7, and 8. Among the SDG 9 targets considered, target 9.2 again exhibits the highest number of trade-offs, whereas targets 9.4 and 9.5 show the most positive interconnections, extending to nearly all SDGs, including SDG 9 itself.

Across the studies considered, SDGs 7, 8, and 1 are consistently highlighted across multiple sources as strongly connected to other goals. The repeated emphasis on these SDGs suggests that industrial innovation, energy, economic growth, and poverty reduction are key leverage points within the broader SDGs framework.

Finally, the literature review highlights the absence of a shared methodological approach for systematically measuring the interactions among the different Sustainable Development Goals. In this context, the Italian National Strategy for Sustainable Development represents a valuable framework for grouping and identifying these interlinkages. For this reason, the strategy will be used in this thesis as the foundation for developing a questionnaire aimed at exploring the role of innovation in advancing the SDGs.

Before addressing this analysis, however, it is essential to understand how innovation can be accelerated through the technology transfer process, which transforms the outcomes of scientific research into practical applications and facilitates the diffusion of innovation. Indeed, effective technology transfer is a key mechanism through which scientific knowledge is translated into concrete innovations.

4 ENABLING SUSTAINABLE INNOVATION THROUGH TECHNOLOGY TRANSFER

Technology transfer (TT) is the process through which knowledge and research results are transformed into economic value, promoting growth and innovation. It represents one of the most delicate phases in the innovation process, as it requires collaboration between diverse stakeholders — such as research institutions and companies — who must share knowledge, skills, technologies, and sometimes employees. At the same time, it is essential to protect the intellectual property of inventors and respect the rights of any research and development funders. Effective technology transfer is therefore crucial, as difficulties in this phase often determine whether an idea successfully becomes a true innovation. In fact, new inventions can become innovations only if their technology transfer is possible.

The main challenge lies in bridging the gap between two very different worlds, each with its own goals, needs, and even language. Public research focuses on developing cutting-edge knowledge and technologies whose practical applications often take time to materialize. In contrast, companies require technological solutions that are not only effective but also economically viable and ready for rapid, if not immediate, implementation, sometimes missing a medium-long term vision. It is therefore essential to promote a stronger entrepreneurial culture within universities and research institutions through initiatives that reinforce a vision based on a **knowledge exchange approach** and encourage researchers to consider the socio-economic impact of their work.

The shift from an approach focused on “technology transfer” to one centred on “knowledge transfer” or “knowledge exchange” is gaining importance[22], and concepts such as “open innovation” and “co-creation” are becoming increasingly widespread. This means that efforts are being made to move beyond the linear model of technology transfer, in which research is conducted in the laboratory, potential marketable results are achieved, and only then are resources sought to commercialize them.

The most recent initiatives launched at the national and, above all, European level, as well as within ENEA, aim to promote collaborative research and co-creation pathways that bring together the various actors of innovation ecosystems—research, industry, finance, institutional

stakeholders, policymakers, and businesses, including financial institutions and venture funds. The goal is to develop new joint operational models based on a win–win approach for all participants in the process.

According to WIPO [23] - the World Intellectual Property Organization of the United Nations - academic knowledge and innovative technologies are transferred and used for scientific, technical, socio-economic and commercial purposes through a variety of channels, including:

- publications (technical journals, scientific magazines, etc.);
- presentations and personal contacts (conferences, courses, professional organizations, etc.);
- patent documents;
- contract research, sponsored research and R&D collaborations with firms;
- institution-industry staff exchange;
- postgraduate projects;
- students entering the workforce;
- consultancy work by university staff;
- assignment and licensing of technology;
- spin-offs and start-ups.

Encouraging the transfer of ideas and inventions from university and public research institution (PRI) laboratories to the marketplace seeks to benefit society by generating new products, processes, jobs, and innovations.

Among the different entities working as intermediaries to facilitate technology transfer at academic or commercial level there are the University Technology Transfer Offices (TTOs). They are bodies, operating within academic institutions and research organizations, handle intellectual property management, patent licensing, research contracts with companies, and the promotion of start-ups and spin-offs. They serve as the first contact point for researchers and industry looking for new opportunities and promote the exchange of best practices [24].

Common benchmarking indicators used to assess TTO performance include [23]:

- The number of IP disclosures.
- The number of IP applications.
- The number of grants;
- The number of licensing contracts.
- The licensing revenue;

- The number of start-up companies.
- The number of joint ventures.

Knowledge and technology intermediaries can also be found in the business sector with the aim of passing on the latest technological and scientific knowledge to their clients [24].

Since the mid-1990s, universities and research institutions across the Organisation for Economic Cooperation and Development (OECD) countries have had increasing autonomy in deploying their own support programmes for knowledge transfer, leading to the development of a growing number of Knowledge Transfer Offices (KTOs) [24].

Conversely, the creation of these intermediary organisations for knowledge transfer may create an overly complex system. To avoid coordination failures, smaller universities and research institutes with limited human and financial resources that do not have the critical mass to justify setting up a fully-fledged office, could be merged under a unified office and direction.

The European panorama shows that EU continues to be a global leader in terms of scientific output but still lags behind in translating this advantage into products, requiring a multidimensional valorisation strategy.

The effective valorisation of research and innovation (R&I) depends on a well-structured funding ecosystem that meets the financial needs of knowledge-intensive and innovative companies across all stages of their life cycle: from R&D to proof of concept, start-up creation, and business scale-up. While the R&I phase benefits primarily from grant-based funding, once companies enter the market, access to corporate finance solutions and private investment becomes increasingly relevant. Without a robust funding ecosystem, even the most promising spin-offs and start-ups are at risk of bankruptcy. Although significant progress has been made in improving access to finance, the limited number of private investments in early-stage companies remains a key challenge in Europe. Venture capital (VC) plays a critical role in enabling innovative enterprises to grow and scale. Further efforts are needed to establish supportive framework conditions and practical instruments that allow intangible assets, such as know-how and intellectual property, to be leveraged as collateral for growth financing. Notably, start-ups founded by PhD students and academic researchers are substantially more likely to file patents than their non-academic counterparts [24].

Nevertheless, the current landscape is moving away from the simple generation of IP and putting more emphasis on the use of intellectual assets [24]. Intellectual property is the cornerstone for research results to make an effective impact on society, due to its capacity to

give its holders a competitive advantage in the marketplace. We need to foster an IP culture change by providing guidance and support, at both the EU and the national level, not only for IP protection but for its efficient use and management [24].

4.1 TECHNOLOGY TRANSFER IN ITALY

Compared to other European countries, Italy faces a significant delay in technology transfer. There are many reasons for this delay starting from investments dedicated to the TT that in Italy are not comparable with some close countries such as Germany and France. Also, in terms of people employed in the TT sector Italy is well below the average.

Between 2009 and 2023, Italy recorded a significant increase in high-quality STEM publications, which grew by 60 percent [25]. This growth was broadly distributed across different disciplines, with a particularly strong rise in medical sciences, which alone accounted for just over 40 percent of the total increase in quality STEM publications during the period [25].

However, these advances in research have not been matched by comparable progress in patenting, a key condition for the commercial exploitation of scientific results. The gap with other major European countries remains wide: the number of patents filed by Germany and France is about five and two times higher, respectively, than those filed by Italy, as shown in Figure 20.

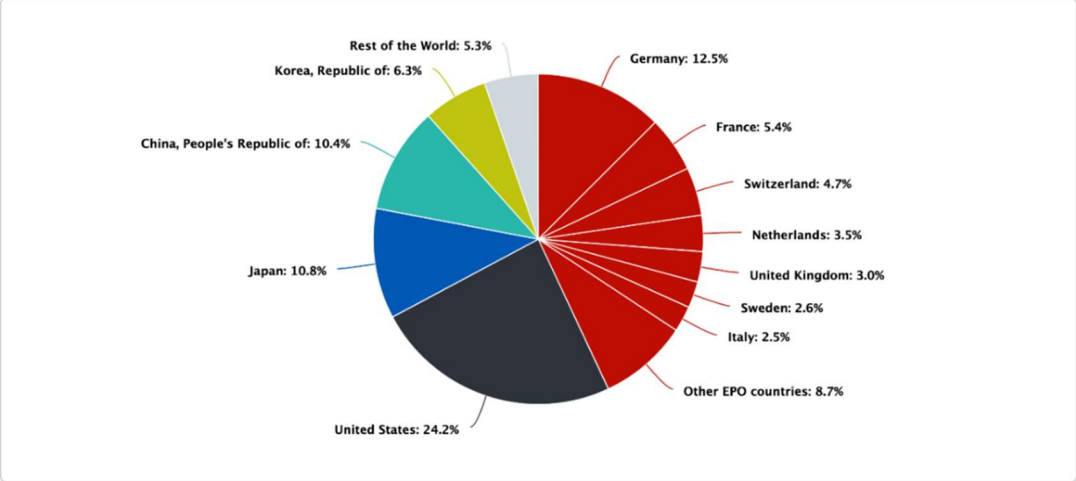


Figure 20: Origin | epo.org Geographic origin of the European patent applications determined by the first-named applicant principle (2024).

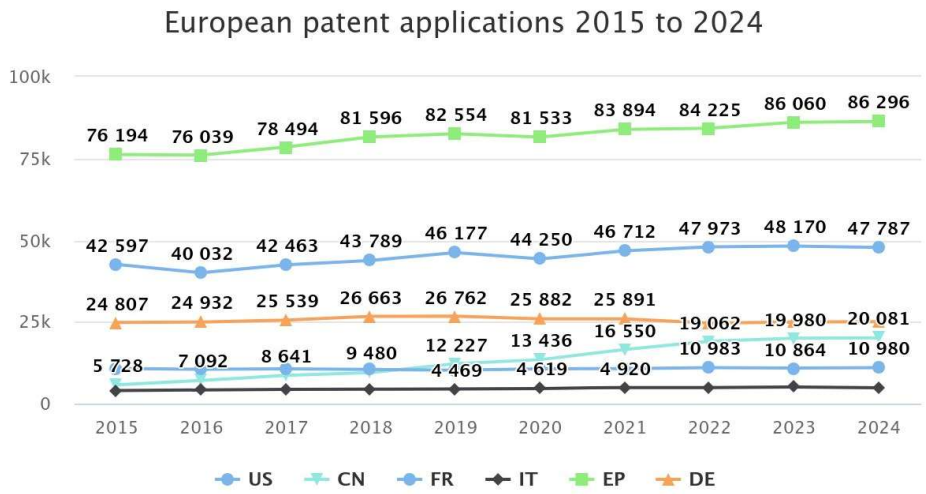


Figure 21: European Patent applications in the last decade from selected countries. Source : https://www.epo.org/en/about-us/statistics/statistics-centre#/customchart

Despite this, Italy has made progress in recent years as patent applications by Italian residents increased by 22 percent between 2015 and 2024 [25], in line with the overall growth of applications filed with the European Patent Office (EPO). Nevertheless, reflecting the country's industrial specialization, Italian patents are mainly concentrated in mature sectors such as logistics, transportation, and civil engineering.

Also, patenting activity in Italy is highly concentrated, with a small group of companies and universities accounting most of all patent applications. The difference for universities consists in a wider portfolio of research fields, relying less on traditional technological fields.

The lag in patenting also mirrors low investment in research and development (R&D). In 2023, Italy's R&D expenditure amounted to 1.31 percent of GDP, well below the European average.

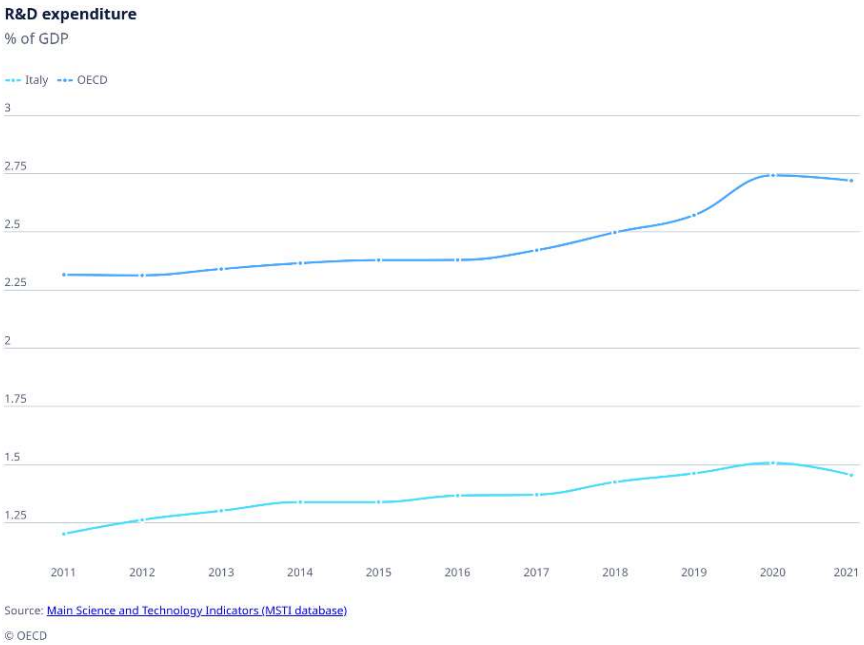


Figure 22: R&D expenditure (% of GDP) in Italy compared to OECD

In fact, among the EU countries, the highest R&D intensity in 2023 was recorded in Sweden (3.64%) followed by Belgium (3.27%) [25]. Overall, in the EU the gross domestic expenditure on R&D stood at €389 billion in 2023, corresponding to 2.26% of GDP, an increase of 58.9% compared with 10 years earlier [26]. Despite this increase, EU's R&D expenditure relative to GDP remained well below the corresponding ratios recorded in Japan (3.44%), the United States (3.45%) and South Korea (4.96%).

The real value of public funding to the university system has decreased by 20 percent following the economic crisis, and despite the higher allocations over the past six years, it remains today at a level 15 percent lower than in 2008 [25].

In Italy University Technology Transfer Offices are smaller than European average. Many institutions established TTOs following the abolition of the "professor's privilege," which granted researchers ownership of IP. For the same number of patent families managed in Italy we count on average 5.7 full time employees, while the European average is 11, meaning about 20 percent [25] fewer staff.

Also, in terms of economic valorisation, Italian TTOs have lower average revenues than their EU counterparts. There are critical issues related to cash flow, since the costs of protecting intellectual property come before the revenues.

The number of TTOs is highly concentrated: in the top five universities and public research institutions by number of patents (Politecnico di Milano, National Research Council (CNR),

Politecnico di Torino, Italian Institute of Technology (IIT), and the University of Bologna) the size of the TTOs (18 full time equivalents) is consistent with that recorded in the main European universities in terms of patents in their portfolios [25].

Notably, Italy is among only five EU-27 countries that employ unified metrics for knowledge transfer, representing a commendable step toward greater transparency and effectiveness. European TTOs should adopt standardized metrics to strengthen performance evaluation and facilitate meaningful benchmarking. By systematically monitoring key indicators, TTOs can better identify strengths, weaknesses, and emerging trends, thereby enhancing their capacity to translate research into societal and economic value.

Finally, the analysis given by *"Ricerca, innovazione e trasferimento tecnologico in Italia"* by the Banca d'Italia finds three main challenges of the Italian technology transfer system, that are interrelated, and that could be addressed through the implementation of effective policies:

- Availability of resources,
- Insufficient operational scale,
- Organizational and legal constraints and complexity.

Another important tool to that facilitate knowledge transfer between universities and industry are university spin-offs and start-ups. They foster innovation ecosystems that drive regional economic growth, they generate high-skilled employment, attract investment, and contribute to the formation of technological clusters.

Interestingly, a positive figure stands out on this field: since 2017, Italy has emerged as the leading country in number of spin-off production, contributing a substantial 27.31% to the total, followed by Germany 17.11% [27].

Finally, delays and critical issues still need to be addressed within the Italian technology transfer context. Technology Transfer Offices need to grow in size and expand their activities. In this framework, this thesis will examine and explore a virtuous case of technology transfer carried out by ENEA, which is taken as a case study to further investigate the role of technology transfer in advancing the Sustainable Development Goals.

4.2 TECHNOLOGY TRANSFER AND SDGS

After having understood what technology transfer is and what are its main tools, potentialities and critical aspects, and after having clarified the concept of interlinkages and the role of SDG 9, we may now see some interconnections among those concepts.

Technology transfer operationalizes SDG 9 in three main ways:

1. Improving industrial processes and infrastructure (Target 9.4)

When research organizations transfer new technologies to companies, industries can modernize their production systems, reduce emissions, increase efficiency, and build better infrastructure. For example, when a new energy-efficient manufacturing technology is licensed to a firm thanks to an effective TT they will innovate their production process to be more sustainable.

2. Enhance scientific research, technological and innovation capabilities in industrial sectors (Target 9.5)

TT promotes knowledge exchange from research institutions to businesses. This expands firms' ability to innovate and increases collaboration between researchers and industry. TTOs can develop dedicated initiatives for joint research projects or sharing laboratories and expertise, enabling researchers to address challenges arising from industrial needs.

3. Supporting the development of high-technology sectors an industrial diversification (Target 9.b)

Through patents, prototypes, and pilot projects, TT helps countries expand into more advanced industrial sectors. Research institutions can align technology transfer portfolios with strategic sectors such as energy and the circular economy that demonstrate stronger connections with the Sustainable Development Goals, bringing positive impacts across all dimensions of sustainability.

As already discussed in the chapter on interlinkages, progress towards SDG 9 generates spillover effects—mostly positive—across many other SDGs.

Through interlinkages, these mechanisms propagate benefits to SDGs 1 (No Poverty), 7 (Clean energy), 8 (Economic growth), 12 (Responsible production), In fact, new technologies create jobs and boosts productivity, generating economic opportunities. Additionally, many transferred technologies improve energy efficiency and support renewable energy production or strengthen more efficient industrial processes reducing waste, pollution, and resource use.

This is why technology transfer is considered a cross-cutting enabler of sustainable development.

On the other hand, interlinkages may show some trade-offs. Some technologies, especially those involving materials, chemicals, or resource and energy-intensive processes, can create negative side effects if not well managed. Strong governance is required to mitigate trade-offs particularly with SDGs 6, 14 and 15 as emerges from the interlinkages analysis.

Again, TTOs can develop technology transfer initiatives and portfolios with strategic innovative sectors that demonstrate stronger connections with the Sustainable Development Goals.

A relevant example is provided by Oxford University Innovation (OUI), which periodically publishes an *Impact Report* based on surveys addressed to its spin-off companies and startups directly.

Oxford University Innovation (OUI) helps transform the University of Oxford's world-leading knowledge and research into innovation-led impact that shapes industries and improves lives. OUI's support has been instrumental in enabling their research to have real-world impact [28].

As stated on OUI Impact Report website: "We want to understand how their work is improving lives and addressing society's most urgent challenges. Our impact methodology aligns to the UN SDGs which gives us a framework for evaluating how these companies are contributing to positive change. SDGs aim to achieve 'peace and prosperity for people and the planet'" [28].

Through qualitative and quantitative questionnaires, OUI collects information on the metrics by which the companies themselves measure the impact of their products or services. This approach makes it possible to assess impact even in contexts characterized by different levels of technological maturity, acknowledging that impact may take different forms depending on the sector and stage of development.

OUI has a large portfolio with many early-stage companies, and while some ventures are already delivering measurable change, others are still building their foundations. This is a represents a great challenge to collect structured and comparable data.

In the next Figure an example of how Oxford University presents a technology in the OUI Impact Report 2025. The sheet contains a synthetic description of the technology, an "Impact" section picturing the benefits apported by it, all the activities of the TTO involved, a striking quote by the owner of the technology, and finally, the SDGs addressed.

IMPACT

Case study

Macrocosm: Modelling the global economy for a sustainable future

From politicians to investors, decision makers face an increasingly unpredictable and interlinked world. Economic forecasting has long struggled to keep pace, and traditional models often oversimplify the intricacy of modern economies. Before the 2008 financial crisis, macroeconomic models failed to give proper warning because the root of the crisis – companies and banks not paying their debts – was too complicated to factor in.

Leaders navigating high-stakes transitions – such as the shift to clean energy – need intelligent decision-making tools purpose-built for the complexity of today's world. Macrocosm, a spinout from the University of Oxford's Social Sciences Division, is building those tools.

Founded by Professor Doyne Farmer, a world-renowned economist in complex systems, Macrocosm builds next-generation economic models that simulate how companies and investors make real decisions, replacing abstract trends with detailed logic.

Macrocosm's first focus is the global energy transition. With support from the Clean Prosperity Foundation in Canada, the team has developed models to guide Canada's national energy policy. In Japan, Macrocosm partners with insurance company Aioi Nissay Dowa to improve the modelling of supply chain risk, helping the company better price and manage that risk for its clients. A US National Science Foundation grant, meanwhile, is funding Macrocosm's work on a global energy investment and risk simulation platform.

At the heart of Macrocosm's platform is a 1:1 scale simulation of the global energy system, including companies and the assets they own. Unlike existing solutions, this 'digital twin' will be empirically validated using vast amounts of data and embedded with industry-specific domain knowledge. The goal is not just insight, but practical impact – building tools that investors, governments and companies can use to make better long-term decisions for the energy sector.

Macrocosm, spun out just two years ago with expert support from OUI, is already working on international projects. The long-term goal, says Professor Farmer, is to do for economic planning what Google Maps did for traffic planning – to build a global resource that helps leaders make smarter, more sustainable decisions based on how the economy actually works.

Impact

- **Supply chain model is based on Oxford University research that predicted the economic impact of COVID-19 on the UK economy with remarkable accuracy (a predicted decline of 21.5% in GDP vs actual decline of 22.1%, Q2 2020)**
- **Global energy system model is validated using 20+ years of financial and operational data from more than 30,000 firms and more than 150,000 individual assets**
- **Significant interest in Macrocosm's solutions from some of the world's largest financial institutions (each with more than £300bn assets under management)**

'The model we developed in partnership with Macrocosm – drawing on their expertise in agent-based modelling and combining it with Aioi's advanced data science capabilities – enables us to quantify production risks triggered by natural disasters with remarkable precision.'

Jun Ikegami
CEO, Aioi R&D Lab Oxford

OUI activities

Project management | IP identification & protection | Licensing & contracts | Communications & marketing | Company creation & growth

SDGs addressed

Figure 23: Example record of a "case study" from OUI's Impact Report 2025

It is important to explore SDG interlinkages also in the Italian context, as they represent a valuable opportunity to enhance the impact and visibility of technology transfer outputs from research institutions. The following chapter examines a virtuous Italian case: ENEA and its technology transfer activities.

5 ENEA AND TECHNOLOGY TRANSFER

5.1 TECHNOLOGY TRANSFER DIRECTORATE

ENEA is the "National Agency for New Technologies, Energy and Sustainable Economic Development" a public body established in the 1960s. Its key strengths have always been applied research, technology transfer, and technical-scientific support for companies, associations, regions, and both central and local administrations. Its institutional reference body is the Ministry of the Environment and Energy Security.

Among the many fields of specialization we find: energy technologies (renewable sources, storage systems, smart grids), in which the Agency also coordinates the National Energy Technology Cluster; nuclear fusion and safety (where it serves as the national coordinator for research); energy efficiency (through the National Agency for Energy Efficiency); technologies for cultural heritage; seismic protection; food safety; pollution control; life sciences; strategic raw materials and climate change.

Today ENEA supports the production system and public authorities, particularly the Ministry of the Environment and Energy Security and the Ministry of Enterprises and Made in Italy, in the transition toward a circular economy and resource efficiency.

The Agency employs over 2250 staff members as of June 2025 [Enea.it], distributed across its various offices all over the country, in 14 research centres and among different departments either technical or administrative. Furthermore, ENEA has currently 962 recorded patents.

The Technology Transfer Directorate (TTEC) represents the Agency towards the potential market for research and high value-added technical-scientific services. As their website (www.innovazione.enea.it) states, their mission is: "We are the front end for companies, institutions, and other stakeholders seeking to become innovative and sustainable through ENEA's wide range of services. We support value creation by providing expertise, patents, digital platforms, high-level technical and scientific services and, more broadly, assets, from ENEA to businesses and public administrations, fostering the country's growth."

The Technical Directorate of TTEC, is organized into up to three hierarchical levels:

- Services – Technical-scientific structures and an administrative structure at the second organizational level, reporting directly to the Director of the Directorate.
- Division – A second-level organizational structure of Particular Importance, reporting directly to the Director of the Directorate.
- Services – Third-level technical-scientific structures reporting to the Division.

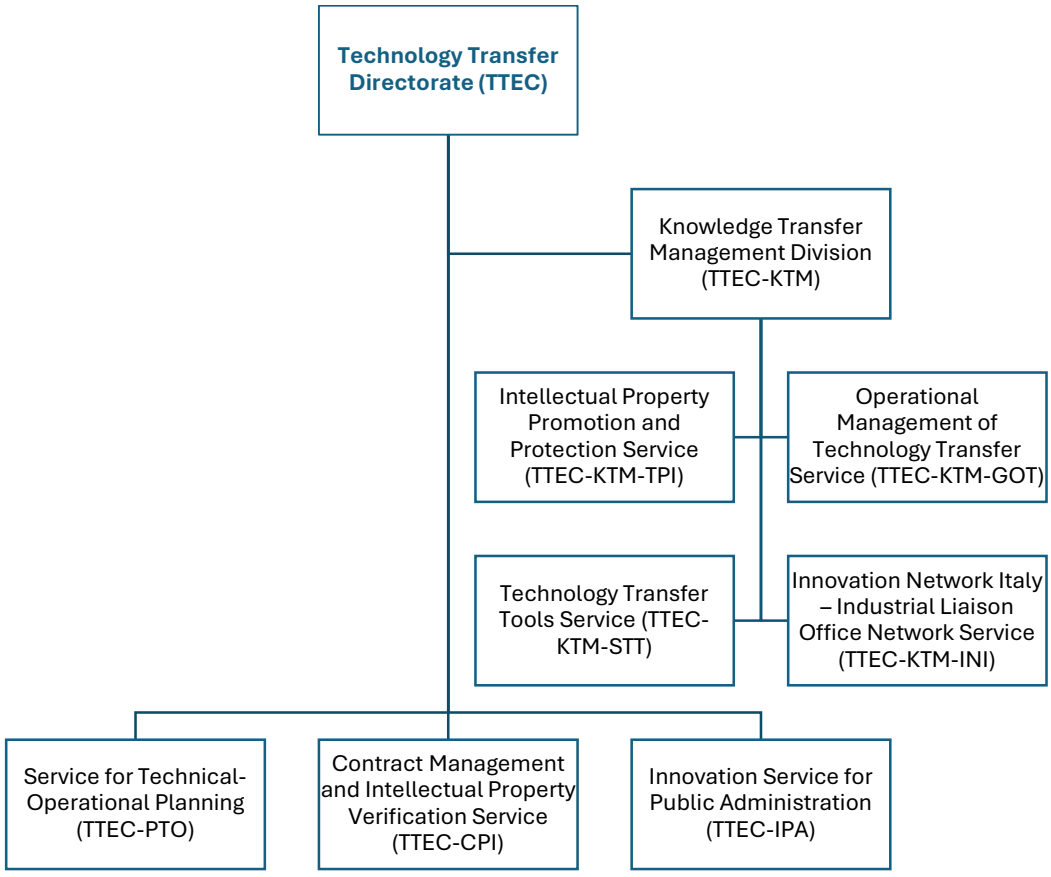


Figure 24: organizational structure of the Technology Transfer Department

As already mentioned, the department offers many services, among which the main tasks and functions can be summarized as follows:

- It adapts and updates the initiatives and tools dedicated to technology transfer, also following studies and analyses concerning the potential and value of ENEA's offerings in various application sectors and industrial supply chains.
- It maps ENEA's range of offerings, proposes and coordinates initiatives for scouting research results and outputs to enhance their value for third parties, and contributes to the assessment and identification of potential application sectors.

- It supports the dissemination of ENEA's research results, expertise, and high value technical-scientific services to public and private subjects, in order to promote collaboration in the areas of research, development, and technological innovation.
- It prepares reports on ENEA's positioning and performance in EU-funded programs and projects, research-related or not.
- It oversees, in coordination with the Departments, ENEA's initiatives and activities in the field of Development Cooperation, with the Innovation Service for Public Administration (TTEC-IPA) facilitating communication and interaction between citizens and ENEA.
- It provides legal and administrative support to ENEA in ensuring the proper regulation of Intellectual Property (IP) and confidentiality within agreements and contracts to be entered into with third parties. It drafts and negotiates, in collaboration with the service of Contract Management and Intellectual Property Verification and the TTEC-KTM Division and Departments, contracts related to technology transfer as well as collaborations and/or services with high technical-scientific content for third parties. The Service also supports the Directorate's units on legal matters concerning policy and operational acts within their areas of responsibility.

5.1.1 ENEA's Atlas of Cooperation for Development

In the framework of IPA Service activities, an Atlas of Development Cooperation is developed. The Atlas provides an overview of projects and initiatives supporting sustainable development partnerships. In fact, the Agency works for development cooperation mainly through networking and partnerships, technology transfer and training.

To strengthen technology transfer in developing countries and showcase its expertise to stakeholders in the field, ENEA has developed the "Atlas of Technologies and Projects for the 2030 Agenda and Development Cooperation."

It is an online database containing technical data sheets on projects, agreements, and technologies carefully selected following the principles of sustainability, optimization for local contexts, and the promotion, where possible, of synergies with national entities.

Research on this data sheets con be filtered on an SDG criterion, which allows – for the purpose of this thesis – the highlight how SDG 9 (innovation) is entwined with other SDGs.

Table 6: Atlas of Technologies and Projects filtered by SDG 9

[https://www.atlanteperlacooperazioneallosviluppo.enea.it/le-schede-dellatlante-enea.html]

Technology	**SDG**				
Aerated biocement for sustainable construction	9	11			
High-precision solar compass	9				
Identification of Best Available Techniques (BAT) and Best Environmental Practices (BEP) in the metallurgical industry	9				
Automated management system for biological wastewater treatment plants	9	6			
Solutions aimed at optimizing off-site construction supply chains for the redevelopment of the built environment	9	7	11	12	13
Development and characterization of innovative materials for construction	9	7	11		
Project	SDG		Beneficiary Countries		
Technical assistance to UNIDO for reducing unintentional emissions of persistent organic pollutants from the metallurgical industry	9		Central Asia, Europe, various countries (Eastern and South-Eastern Asia (ESEA); Central and Eastern Europe, Caucasus and Central Asia (CEECCA))		
Climate model data processing for impact studies on agricultural production in Africa	9	13	Ethiopia		
Support to Botswana's early warning system	9	13	Botswana		
Support to the Sudan Meteorological Authority in strengthening the national weather early warning system	9	13	Sudan		

The SDGs addressed to SDG 9 in the Atlas are largely consistent with those identified as interlinkages with SDG 9 in the previously cited sources of Chapter 3.3 of this thesis- Interlinkages among SDGs.

The Atlas also lists the agreements in force with international institutes and organizations mainly acting in development cooperation.

In this database, SDGs are selected subjectively by the owner of the technology or the project and, since the type of interaction is not specified, only synergies and positive contributions are considered. Innovative technologies play a pivotal role in addressing the challenges set by the 2030 Agenda. ENEA actively contributes to the transfer of technologies and know-how to developing countries, carefully tailored to local contexts, fostering synergistic exchanges of knowledge in close collaboration with businesses and other actors within the innovation system.

This Atlas therefore explores technologies and projects aimed at developing countries, where the focus of the 2030 Agenda is primarily on SDGs related to ending poverty and hunger, promoting health and education, ensuring the availability of clean water, and expanding access to energy, with the broader goal of reducing inequalities between countries.

In more developed countries, such as the European case and Italy, innovation tends to focus on different SDGs, particularly those related to climate action and ecosystem protection, the development of resilient infrastructure, the promotion of sustainable cities, and responsible production systems. This is the same difference of geographical and temporal scales that may generate varying kinds of impact already seen in Chapter 3.3 with the KnowSDGs European interlinkages database.

As a result, the SDGs that play a central role in different contexts are scale-dependent, making it relevant to assess which SDGs are most strongly addressed by ENEA's innovative technologies within the Italian innovation context.

5.2 ENEA INNOVATIVE APPROACH FOR TECHNOLOGY TRANSFER

The following section outlines several initiatives carried out by the Technology Transfer Directorate, with the underlying idea is that only by investing in a stable and long-term network of relationships with businesses and public authorities, and by developing autonomous

financial instruments, can the conditions be created to significantly increase the number of ENEA technologies utilized by the production system.

Starting from the 2018–2020 Three-Year Activity Plan (PTA), ENEA adopted a new strategy specifically aimed at shifting the focus of its technology transfer activities; the two pillars of ENEA's strategy are the KEP and the PoC.

5.2.1 Knowledge Exchange Program (KEP)

The Knowledge Exchange Program (KEP), inspired by MIT's Industrial Liaison Program, was created in 2019 to strengthen ENEA's relationships with the production system through an Open Innovation approach. The KEP represents an evolution of the tool developed by ENEA several years ago, the Atlas of Technological Innovation, to spotlight its portfolio of technologies and advanced services. In its implementation, ENEA has collaborated with the country's main business associations, including CNA, Confapi, Confartigianato, Confindustria, and Unioncamere [29].

It is the Knowledge Transfer Management Division of ENEA's TTEC-KTM who manages the Knowledge exchange program and currently, 251 companies [29] have joined the KEP.

The goal of the KEP is to consolidate, in the medium to long term, the relationships between ENEA and businesses, to align industrial priorities with the Agency's knowledge assets, to provide a high-quality innovation offering and to foster the development of joint and innovative research and projects. It is a tool that ensures a more effective management of interactions with the business sector, while on the one hand preserving broad freedom of action for research staff and, on the other, providing greater opportunities for collaboration and some form of incentive.

On the KEP portal (www.kep.enea.it), the know-how and expertise of ENEA's researchers are showcased, with the ongoing and completed projects, available research infrastructures, and ENEA's patents. The portal is organized around six technological areas identified as priorities for the Agency and for enhancing the industrial system [https://www.kep.enea.it/]:

- Security of critical infrastructures
- High-tech medical tools
- Extreme diagnostic expertise and technology
- Technology for cultural heritage
- Biotechnology for health and nutrition

- Energy production and optimization of energy use

Facilitating contact, fostering an ongoing and dynamic dialogue, and managing mutually beneficial collaborations are some of the key advantages that the Portal aims to provide [30].

Moreover, companies registering in the program can request personalized consulting from a Knowledge Exchange Officer (KEO), a senior researcher specifically trained to identify the expressed or potential technological innovation needs of partner companies and to propose the most effective solutions to satisfy them.

The Knowledge Transfer Management Division is also working on the new KEP 2.0.

The Knowledge Exchange Program 2.0 (KEP 2.0) project was submitted under Line 4 of the 2022 TTO Call for the financing and strengthening of Technology Transfer Offices, and it is funded by the European Union – NextGenerationEU under Italy's National Recovery and Resilience Plan (NRRP), Mission 1 *"Digitalization, Innovation, Competitiveness, Culture and Tourism"* – Component 2 *"Digitalization, Innovation and Competitiveness in the Production System"* – Investment 6 *"Industrial Property System"*. One of the new goals is to broaden the technological areas of interest to Materials and Circular Economy, that are regarded as highly attractive themes for businesses, with cross-sector relevance.

The KEP could also become a tool available to other EPRs, serving as a hub where companies operating in the same or related sectors can meet to initiate collaborations. Ultimately, it could also act as a pool for selecting partners to develop research projects in response to funding calls or to carry out Proof of Concept initiatives financed through internal resources or venture capital [30].

5.2.2 Proof of Concept (PoC)

The goal of the Proof of Concept (PoC) program is to assess the technical feasibility and market potential of ENEA technologies with relatively low Technology Readiness Levels (TRLs), in collaboration with industrial partners. In fact, most of the results of research carried out by universities and public research institutions hardly reach a level of Technology Readiness Level (TRL on a scale from 1 to 9) sufficient to attract the private investments needed to bring them to market and, consequently, to generate a real impact on our socio-economic systems [31].

In the early stages of innovation development, the product is often still immature, and in many cases, the target market itself has yet to emerge. As the technology evolves, it may take on new forms, leading to different products and market applications than originally envisioned.

Consequently, for technologies with a low TRL, the market value proposition remains uncertain, making it challenging to assess the potential return on investment for further development [31].

The PoC program aims to promote the commercial valorisation of ENEA's knowledge, primarily through licensing. For innovative ideas with a TRL between 2 and 4, ENEA offers funding of up to €50,000 (in 2020) to cover the direct costs of a 12-month development project, carried out in collaboration with an industrial partner contributing in-kind resources only (Phase 1). For technologies with a TRL between 4 and 6, ENEA provides funding of up to €100,000 (2020), covering up to 50% of direct project costs for projects lasting up to 24 months, in collaboration with an industrial partner that contributes both in-kind resources and co-financing (Phase 2) [22].

Since the early 2000s, the United States has established proof-of-concept programs aimed at accelerating the commercialization of inventions developed in university laboratories, such as those at the University of California, San Diego, and the Massachusetts Institute of Technology [31].

The main distinctive feature of the ENEA PoC Fund is its competitive nature, financing only those projects carried out in partnership with an industrial collaborator that meets specific economic and financial reliability requirements, operates in the relevant market, and can provide technical and innovative input to the project's implementation [22].

In recent years, Italy has also experienced significant growth in proof-of-concept programs, funded either internally by some universities (such as the Polytechnic University of Turin and the University of Bologna) and research institutions (like ENEA), or through government funding [31].

The most significant challenge, however, lies in establishing concrete collaborations with venture capital (VC) funds. The goal is to combine ENEA's internal PoC funding with external VC resources across various technological specializations, thereby creating critical mass and real market opportunities [22]. In fact, the financial participation of industrial partners in PoC projects, although limited and proportional to the achieved TRL level, could help identify and engage only those partners genuinely interested in establishing a strategic innovation partnership with ENEA [31].

The true value of these programs lies in enhancing the overall technological potential rather than focusing on individual transactions. Their strength is in building lasting relationships with companies and investors interested in innovation and willing to collaborate in developing new technological solutions in a mutually beneficial way [31].

5.2.3 Database of Private contracts

This database supports the analysis of technology transfer demand with the aim of maximizing its productivity and ensuring increasingly effective services for the benefit of the Agency and its Departments. The main objectives of the "ENEA Contracts with Private Entities" database are:

- to make ENEA's collaborations with the private sector visible and easily accessible;
- to provide a service to ENEA Departments by helping them enhance the effectiveness of ongoing collaborations;
- to maintain a historical record of completed collaborations.

Each year, the Technology Transfer Tools Service (TTEC-KTM-STT) conducts a survey of ENEA's new contracts with the private sector. For each Department, a designated contact person submits an annual report detailing the contracts established during the year.

Collaborations are formalized through various types of agreements, the main ones being Memorandum of Understanding, Collaboration Agreements, commissioned and collaborative research contracts, Proofs of Concept (PoC), and other institutional arrangements.

The database collects, standardizes, and integrates the information obtained, complementing it with additional data extracted from contractual documentation.

As of 2025, the database includes 338 registered contracts. For each contract, information is available on the contract code, subject, type of agreement, thematic areas (including application verticals), the involved unit, the ENEA contact person, and the contract start and end dates.

Regarding counterparties, for which 368 records are available, the database includes the organization name, VAT number or fiscal code, type of organization, contact person, region, and website.

The database is structured to generate reports based on various menu categories, such as those listed above, and to perform customized queries for different purposes, including the research of potential partners for project proposals and for inviting stakeholders to events.

5.2.4 Atlas of Innovation

The ENEA Atlas of Innovation represents a comprehensive survey of innovative technologies, processes and services, and technological solutions for businesses, public administrations, and citizens, resulting from ENEA's research activities.

The catalogue consists of a collection of “content types” within Plone, a Content Management System (CMS), that is, a multiplatform content management system used to build and manage websites. The Atlas contains more than 300 technology data sheets, which can be selected by national cluster and ATECO code. These profiles cover over twenty sectors, and each is presented concisely and according to a standardized format.

Its main strengths lie in the relative completeness of the description of the technologies included, the uniform presentation format, and the uniqueness of the product, which brings together, in a single catalogue, technologies from different sectors and research groups that often have little interaction, and whose outputs are otherwise scattered across various ENEA websites.

The main weaknesses concern the updating process and the lack of a formalized internal procedure for revision and population, which relies on a voluntary basis, with staff from the TTEC Directorate responsible for manually updating the catalogue.

Another critical issue is that the IT system used to catalogue the technology profiles is not a proper database. As a result, it lacks a structured classification system that would enable more effective grouping of technologies for targeted promotion to specific stakeholders, significantly limiting search and retrieval capabilities for both external users and internal purposes.

5.3 MATRICS: THE NEW TECHNOLOGY OFFER CATALOGUE

Within the framework of ENEA’s Technology Transfer Plan, the Technology Transfer Directorate (TTEC) is responsible for the systematic mapping and promotion to third parties of the Agency’s assets.
To this end, the Directorate has developed a database with an innovative and dynamic structure that places ENEA’s laboratories at its core. The objective is to maintain an always up-to-date catalogue of ENEA’s entire offering, conceived both as an internal consultation tool for staff and to facilitate the external valorisation of ENEA’s offerings by the TTEC Directorate. The database, in fact, is managed by the TTEC-KTM- STT.

The database is called MATRICS (Management of ENEA’s Intellectual Property and Specialized Competencies). It builds on the legacy of ENEA’s Technological Innovation Atlas and the fact sheets published on the KEP program’s web portal. [32]

The technologies proposed to third parties for potential collaborations and industrial development are categorized by application verticals, with the aim of facilitating engagement with productive sectors and increasing opportunities for collaboration and knowledge exchange.
The compilation of the database fact sheets have involved the scientific representatives of all research activities across the ENEA laboratory landscape, with supervision and validation by their respective line managers. The outcome of this scouting activity, that is intended to be as comprehensive and accurate as possible, will be directed toward companies, public administrations, foundations, and institutions, serving as a knowledge exchange tool and fostering cross-cutting collaborations among departments, divisions, and laboratories within ENEA. [32]

The availability of a single database representing ENEA's technological offering, overcoming the fragmentation of information and integrating the various elements of ENEA's competency portfolio into a single tool, will facilitate and enhance the efficiency of activities aimed at valorising ENEA's Specialized Competencies.

The database does not include the organization's entire technological offering, as this was an intentional design choice. Its purpose is to provide a structured overview of ENEA's technologies made available to third parties, particularly Italian companies. For this reason, including the full catalogue of ENEA's technologies would be unnecessary, given its extensive scope and the significant challenges associated with organizing and continuously updating such a comprehensive collection within a single database.

The total number of products displayed on MATRICS are 235, among which 131 approved and 78 awaiting managers' approval, while the rest is to be revised. In fact, all fact's sheets need to be revised as the text must be accurate while remaining clear and accessible for external users.

Products are distributed among different types and departments. TTEC-KTM has created a "*User Manual*" to help all users in the filling, approval and reading of the data sheets. As explained in the manual, the database's fact sheets are organised indifferent typologies:

- Technologies
- Facilities and infrastructure
- Services

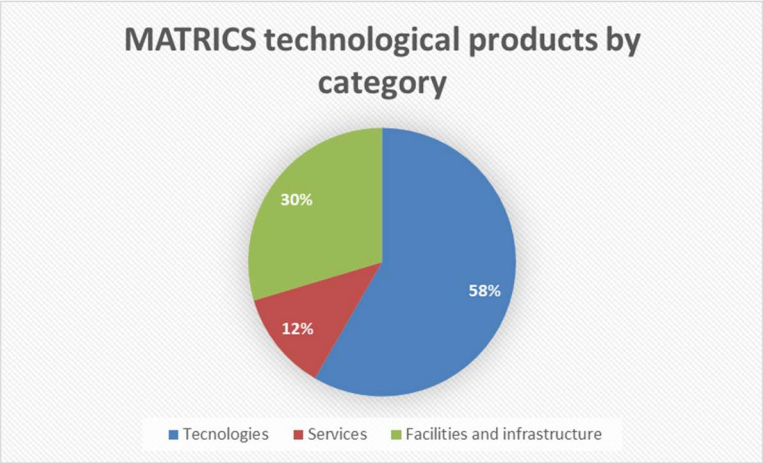


Figure 25: MATRICS technological products by category, personal elaboration

Technologies appear to be the most prominent category among the technological products offered by ENEA. They will be further discussed in the next section.

MATRICS serves both to promote ENEA's portfolio of industrial research results and to support the activities of TTEC colleagues (KTMs, Knowledge Transfer Managers) who, acting as facilitators, assist researchers in their Technology Transfer pathways by accompanying and helping in the identification of external stakeholders, up to the formalization and implementation of the necessary agreements [32].

As anticipated, fact sheets are also grouped into 'vertical' macro-sectors, namely application sectors and industrial value chains.

Verticals and Application sectors:

- Cultural Heritage
- Smart Communities
- Smart industry
- Aerospace
- Agri-food
- Transport and mobility
- Energy
- Chemistry
- Health sciences
- Materials
- Environment and Circular Economy
- Computer science & information technologies

- Innovative approaches and technologies for industries and Made in Italy
- Construction, Monitoring, and Infrastructure Security Management
- Sea and Coastal Economy
- Other

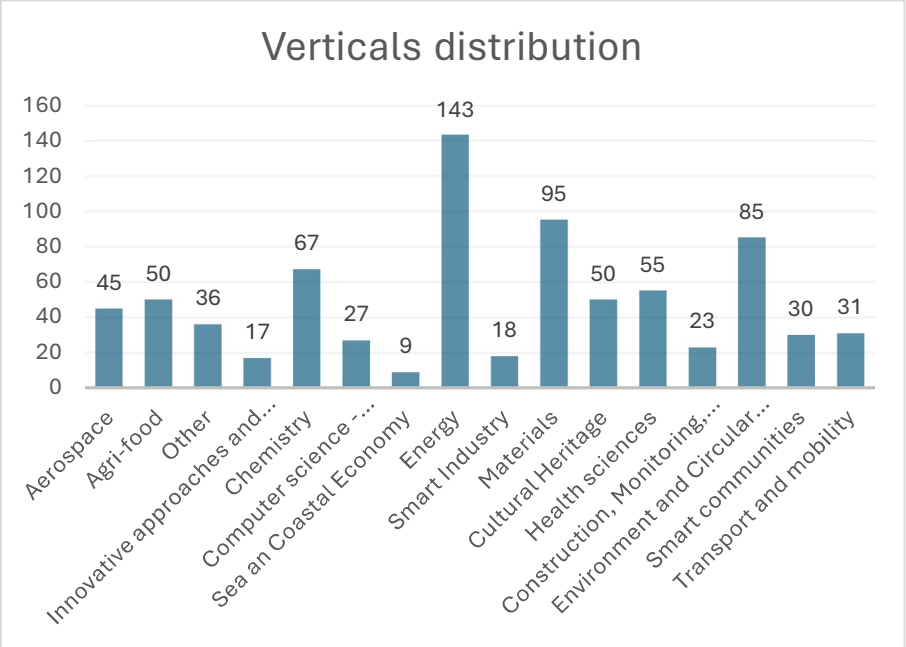


Figure 26: MATRICS technological products by vertical, personal elaboration

MATRCS' offering covers a wide range of verticals, with Energy as the prominent vertical and Sea and Coastal Economy as the smaller one.

Fact sheets can be manged and modified every 6 months, by their OWNER, meaning the person who filled the sheet in the first place.

The technologies are described in detail by the Owner on the data sheets, organized in a table where some essential data are pictured:

- Record ID
- Entry date
- Scientific coordinator
- ENEA unit
- ENEA site
- TRL (technology readiness level)
- Last update date
- Technological offer

- Record title

The descriptive records can be accessed exclusively by ENEA personnel. From these records, output records are derived, which can also be accessed by external users. The output record is intended to attract potential external interest in the ENEA offer; it contains a selection of information, taken from the data entered during the compilation of the database, relating to ENEA technologies, facilities, or services, considered to be of greatest interest to a potential external partner or client. The output record is also available in an English version for the promotion of the ENEA offer in international contexts and it contains: the title and a brief description of the technological offer, its strengths, the technological background, innovative aspects and advantages, application sectors and possible applications, and the TRL, if available.

Figure 27: Output record for MATRICS fact sheet n. 8585

It may be interesting to note how this record is visually different from the Oxford example given in Figure 23 of paragraph 4.2. In the other, more concise example, all the information is presented on a single page, and some important aspects such as technology transfer activities and the SDGs– here not present at all - are simply displayed in the form of icons.

5.3.1 Analysis of ENEA technologies in MATRICS

The targeted type of products for the questionnaire are technologies because they appear to be more cross-cutting across different sectors than other categories and can be more easily

assessed using indicators related to the SDGs. Moreover, these technologies contribute to innovation in the companies that adopt them, and an SDG-based categorization may enhance their attractiveness and encourage their application.

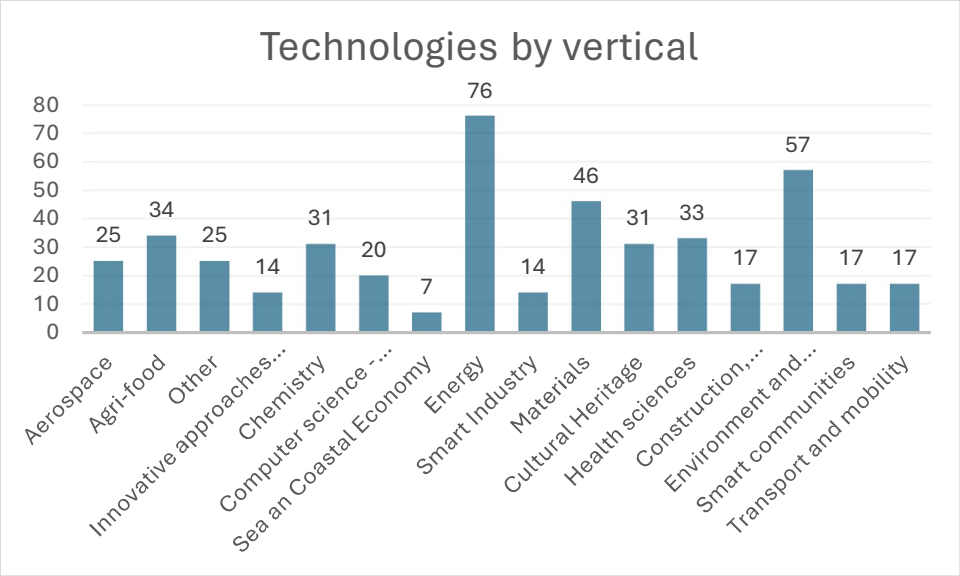


Figure 28: Distribution of MATRICS' technologies by vertical, personal elaboration

As ENEA is the "National Agency for New Technologies, Energy and Sustainable Economic Development" it was to be expected that the developed technologies would primarily focus on Energy (16,8%) and Environment and Circular Economy (15,8%).

Another interesting aspect concerns the divisions present in MATRICS, as they are working on technologies considered as "innovative". In fact, not all divisions are found in the database: as we can see from Figure 29, MATRICS technologies are developed by NUC (Nuclear), SSPT (Sustainability, Circularity, and Climate Change Adaptation of Productive and Territorial Systems), mostly by TERIN (Energy Technologies and Renewable Energy Sources) and DUEE (Energy Efficiency).

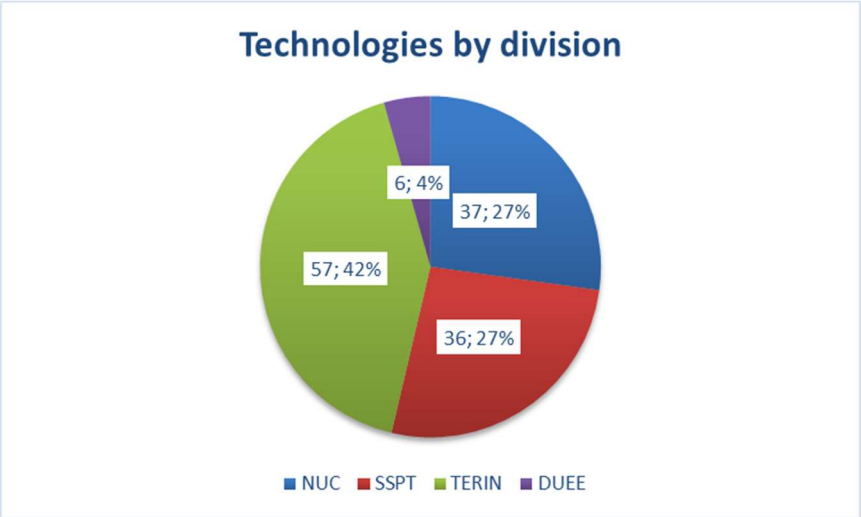


Figure 29: Distribution of MATRICS' technologies by division, personal elaboration

The TRL is a methodology used to assess the maturity level of a technology relative to its commercialization. The TRL is based on a scale from 1 to 9, representing activities ranging from theoretical research and development studies (TRL 1-3) to practical experimentation and technological demonstration (TRL 4-6), up to operational deployment, production, and distribution (TRL 7-9). This is the same scale used in the PoC program mentioned above.

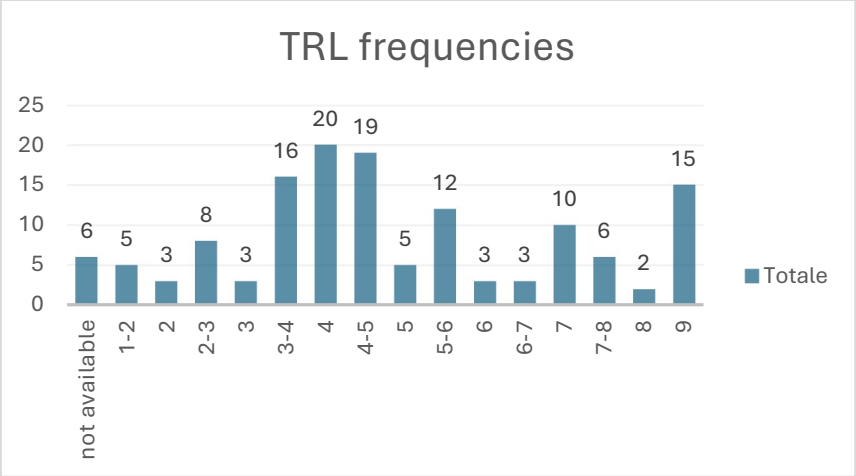


Figure 30: TRL frequencies of MATRICS technologies, personal elaboration

Most of the technologies on the database have a medium TRL, from 3 to 5, meaning that they are under development and practical experimentation.

Not all technologies included in the database are patented. In fact, fewer than half of them are protected by a valid patent. This limited level of patenting reflects the broader Italian context described in Section 4.1 *Technology Transfer in Italy*.

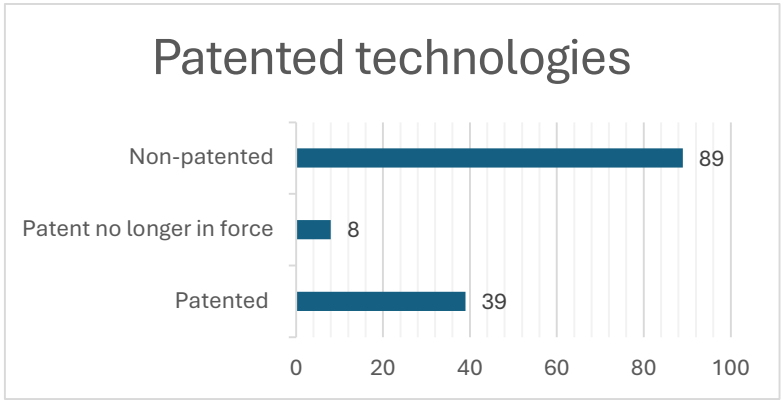


Figure 31: Inclusion of patents within MATRICS, personal elaboration

It should be noted that the records do not include sections specifically dedicated to the SDGs of the 2030 Agenda, as showed in Figure 27. However, there is a section in the form of a questionnaire aimed at highlighting the strengths of the products in the catalogue. One of the identified strengths concerns environmental impact, a category that may appear overly generic or may not be taken into consideration by the owner, as the connections between the various effects generated by a product are not always obvious or easily identifiable.

The data sheets having “Environmental Impact” as a strength are 50 out of 235, meaning that 21.28 % of all products in the database are considered environmental-friendly by the owner.

To determine which SDGs are associated with the technologies, this thesis proposes a questionnaire designed to highlight which SDGs are most strongly connected to and promoted by ENEA’s technology transfer activities. The case study analysis is conducted through a qualitative questionnaire administered to the MATRICS technologies owners.

6 ENEA'S INNOVATIVE TECHNOLOGIES CASE STUDY

6.1 QUESTIONNAIRE DESIGN AND METHODOLOGY

As previously highlighted, the scientific literature currently lacks a consolidated and widely shared methodology for systematically identifying and assessing the connections among the SDGs. Nevertheless, several research institutions and Technology Transfer offices have developed tools and reports aimed at measuring the impact of their technology transfer activities in terms of contribution to the SDGs. A relevant example is provided by Oxford University Innovation (OUI) already explained in section 4.2 of this thesis.

Within ENEA, there are also initiatives aimed at linking technologies to the SDGs, such as the *Atlas of Cooperation*; however, this tool is limited to developing countries. In addition, reports and studies focusing on specific technological areas are available (for example, the AIRI report on decarbonization and the circular economy), but these are not produced on a regular basis and do not systematically cover the entire ENEA technological portfolio nor all SDGs.

A further critical aspect concerns the possibility that researchers or technology owners may overlook certain links between SDGs. This may be due both to limited familiarity with the SDG framework and to the absence of a broader perspective that goes beyond the strictly laboratory-based or technology development level.

Taking into account these considerations and given the absence of a systematic approach within ENEA for presenting the potential contribution of its technologies to the SDGs, it may be useful to develop an ad hoc questionnaire.

The inclusion of SDG references in the MATRICS database records represents an opportunity to enhance the impact of innovative technologies and to increase their attractiveness to the business sector. Companies are increasingly interested in investing in technologies that contribute to the achievement of the SDGs, also in relation to Environmental, Social, and Governance (ESG) criteria, which are becoming ever more relevant in investment decisions.

The adoption of a technology by a company can, in fact, support specific SDGs that are already part of its sustainability portfolio, thus representing a new opportunity for achieving targets of strategic interest.

Furthermore, the analysis of MATRICS technologies targeted at Italian companies can provide valuable insights into the implementation and progress of the Italian National Sustainable Development Strategy.

The case study analysis is conducted through a qualitative questionnaire directed to the owners of ENEA technologies. The sample analysed corresponds to the institution's technological portfolio, and on the basis of the collected results, the contribution of these technologies to the 2030 Agenda and to the NSDS is assessed.

The questionnaire items were designed to relate different aspects, including:

- the SDGs identified a priori by the technology owners;
- the possible presence of quantitative impact analyses related to the technologies;
- the inclusion of technologies in the ENEA Atlas of Cooperation;
- the interlinkages among SDGs identified by the NSDS, which groups goals into strategic "packages", making it possible to highlight relationships that may not be immediately apparent to researchers;
- the type of interaction among SDGs, distinguishing between synergies and potential trade-offs;
- the environmental impact already described in the MATRICS records.

The results of the analysis will contribute to evaluating the potential permanent integration of this section within the MATRICS database, with the aim of collecting structured and comparable information. In this way, the database may draw inspiration from international best practices and strengthen the role of ENEA technologies in supporting the SDGs, while simultaneously facilitating their adoption by companies interested in achieving specific sustainability targets.

The questionnaire is written in Italian, as it is addressed to Italian researchers, and it is designed in order to be as clear as possible, with explanation for every section and an example to explain the meaning of interlinkages with many SDGs and the different kind of links.

Additionally, it must be quite easy and fast to fill out: because of how the questionnaire was designed, consisting of 22 multiple-choice answers and a final open question, the completion time should be around 15 minutes. A suitable length to facilitate and encourage researchers to respond.

While the first 5 questions are multiple choice or yes/no answers, the other 15 questions about the 15 Strategic Choices and their Objectives from the NSDS have three possible answers: Synergy, Nothing, Trade-off. Only 4 Ps are structured into Strategic Choices and are used in the questionnaire: People, Planet, Prosperity and Peace. This is because the pillar Partnership is not structured into Strategic Choices but into macro areas of action that are too general to answer.

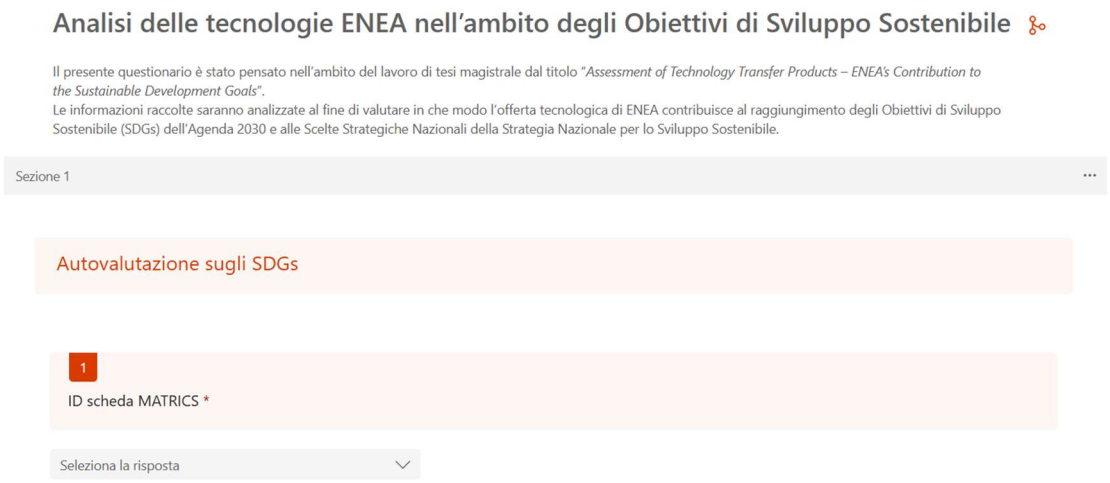
When the design of the questionnaire was completed, a small group of colleagues from the TTEC-KTM- STT reviewed it to make the final revisions before sending it to two owners in order to carry out a pilot test.

Finally, an email was sent from ENEA's official Innovation email address to all the owners of MATRICS' technologies, explaining the context, presenting this thesis and explaining the importance of a dedicated section on the database.

The survey remained open for approximately three weeks, from the 27th of January to the 18th of February.

6.2 QUESTIONNAIRE STRUCTURE

Section 1: Selection of the MATRICS data sheet ID and identification of the SDGs that researchers consider inherently linked to their technologies. The questionnaire also includes a question regarding the presence of a quantitative environmental impact assessment.



2

L'Agenda 2030 delle Nazioni Unite per lo Sviluppo Sostenibile definisce 17 Obiettivi di Sviluppo Sostenibile (SDGs) volti a promuovere uno sviluppo economico, sociale e ambientale sostenibile. **Si prega di indicare a quale/i SDGs dell'Agenda 2030 è potenzialmente riconducibile la tecnologia in fase di sviluppo.** N.B.: L'SDG 9 (Industria, innovazione e infrastrutture) è fortemente connesso allo sviluppo delle tecnologie innovative e si propone di realizzare infrastrutture resilienti, sostenere un'industrializzazione sostenibile e, soprattutto, rafforzare la ricerca scientifica e le competenze tecnologiche. Per questo motivo, l'obiettivo 9 "Innovazione" è considerato comune a tutte le tecnologie di ENEA. *

3

È stata effettuata una valutazione della sostenibilità della tecnologia?

- ○ LCA
- ○ LCSA
- ○ LCC
- ○ Carbon footprint
- ○ Water footprint
- ○ Altro

4

L'impatto ambientale è stato selezionato come punto di forza della tecnologia per la scheda MATRICS?

- ○ Si
- ○ No

5

La tecnologia è presente anche nell'Atlante della cooperazione ENEA? *

- ○ Si
- ○ No

Figure 32: Screenshots from the questionnaire - Section 1

Section 2: Explanation on the National Sustainable Development Strategy and example of a technology of lithium extraction having synergies with SDGs 7 and 13 but trade-offs with SDGs 6 and 14.

Figure 33: Screenshots from the questionnaire - NSDS methodology explanation

Section 3: People's Strategic Choices and National Strategic Objectives

1 Combat Poverty and Social Exclusion by Eliminating Territorial Disparities

- Reduce the intensity of poverty and economic and social inequalities
- Combat material and food deprivation
- Reduce housing hardship

2 Ensure Conditions for the Development of Human Potential

- Increase employment opportunities for socially marginalized groups
- Ensure the full functionality of the social protection and welfare system
- Reduce early school leaving rates and improve the education system

3 Promote Health and Well-being

- Reduce the population's exposure to environmental and anthropogenic risk factors
- Promote healthy lifestyles and strengthen prevention systems
- Ensure access to effective healthcare and care services, addressing territorial disparities
- Promote mental health and well-being and combat addictions

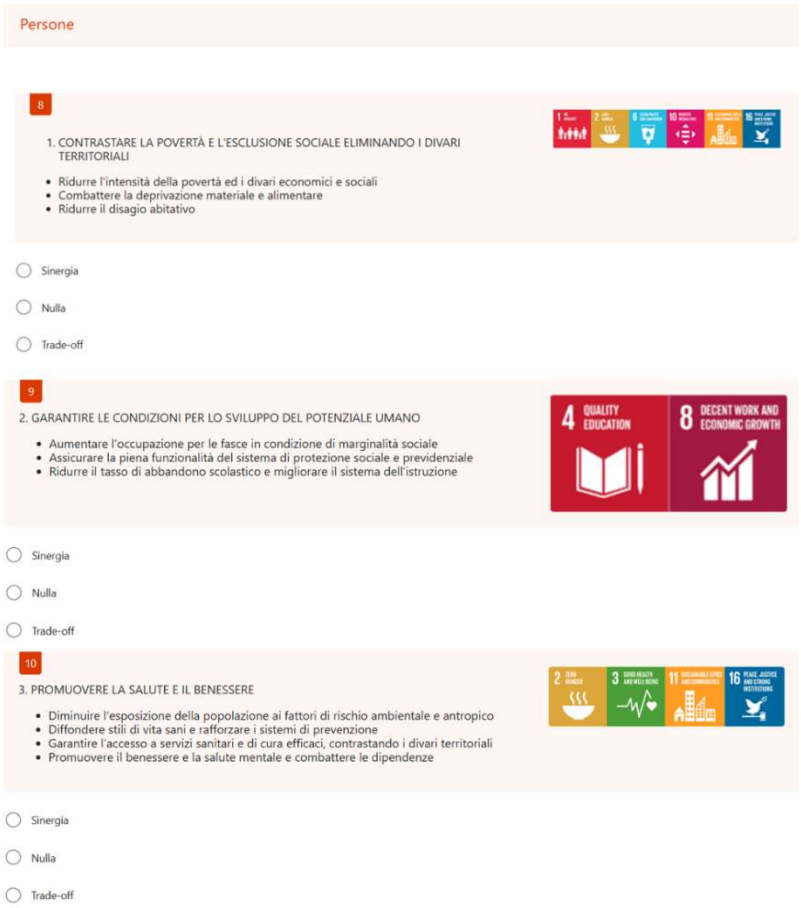


Figure 34: Screenshots from the questionnaire - Section 3

Section 4: Planet's Strategic Choices and National Strategic Objectives

1 Halt Biodiversity Loss

- Safeguard and improve the conservation status of species and habitats of Community interest

- Halt the spread of invasive alien species
- Increase protected terrestrial and marine areas and ensure effective management
- Protect and restore genetic resources of agricultural interest, agroecosystems, and forests
- Integrate the value of natural capital (ecosystems and biodiversity) into plans, policies, and accounting systems

2 Ensure Sustainable Management of Natural Resources

- Maintain the vitality of seas and prevent impacts on the marine and coastal environment
- Achieve land degradation neutrality and combat land degradation and desertification
- Minimize pollutant loads in soils, water bodies, and groundwater, considering good ecological and chemical status standards
- Implement integrated water resource management at all planning levels
- Maximize water efficiency and adjust withdrawals to water scarcity
- Minimize emissions in line with air quality objectives

3 Create Resilient Communities and Territories, Safeguard Landscapes and Cultural Heritage

- Promote land stewardship and maintenance and strengthen the resilience of communities and territories, including with regard to climate change impacts
- Regenerate cities and ensure accessibility
- Ensure ecosystem restoration and defragmentation and foster urban–rural ecological connections
- Ensure the development potential, sustainable management, and protection of landscapes
- Conserve and enhance cultural heritage and promote its sustainable use

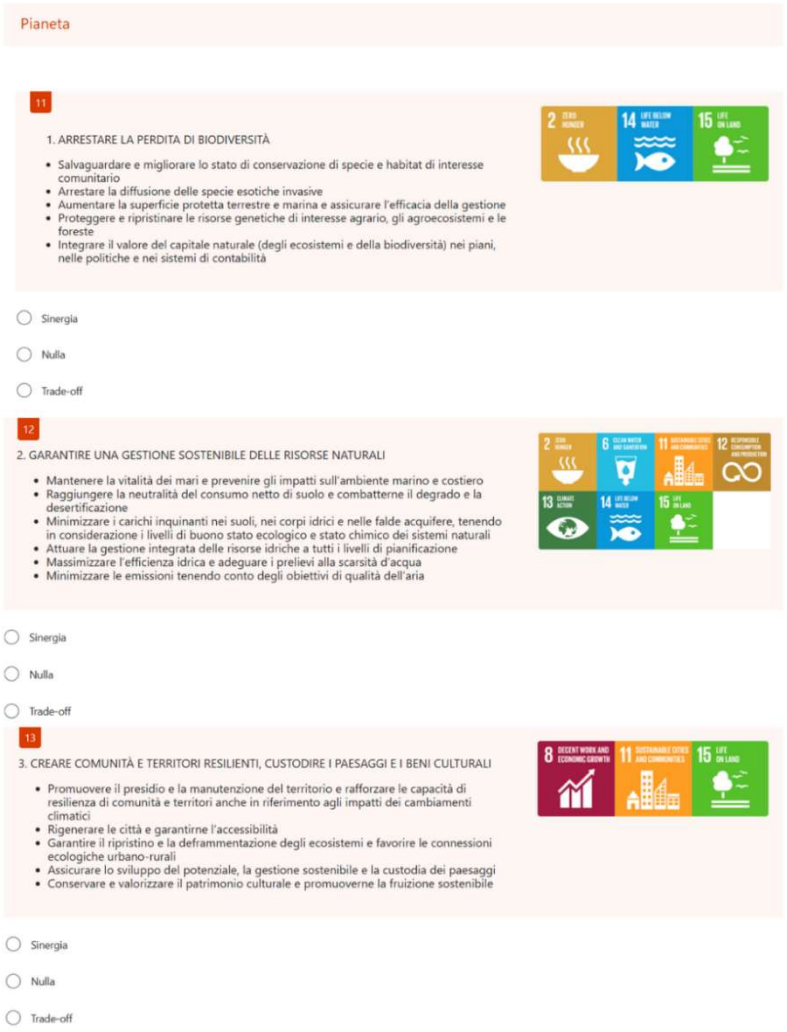


Figure 35: Screenshots from the questionnaire - Section 4

Section 5: Prosperity's Strategic Choices and National Strategic Objectives

1 Promote Sustainable Economic Well-being

- Ensure the vitality of the productive system
- Ensure economic well-being and a fair distribution of income

2 Finance and Promote Sustainable Research and Innovation

- Increase investment in research and development
- Implement the Digital Agenda and enhance the diffusion of smart networks
- Innovate processes and products and promote technology transfer

3 Ensure Quality Employment and Education

- Ensure accessibility, quality, and continuity of education and training
- Increase sustainable and quality employment

4 Affirm Sustainable Production and Consumption Models

- Dematerialize the economy, reduce waste generation, and promote the circular economy
- Implement ecological tax reform and expand the use of sovereign green bonds
- Promote social, environmental, and human rights responsibility in public administrations and enterprises, including through sustainable finance
- Promote demand for and increase the supply of sustainable tourism
- Ensure the sustainability of agriculture and the entire forestry supply chain
- Ensure the sustainability of aquaculture and fisheries along the entire value chain
- Promote Italian excellence

5 Promote Sustainability and Safety in Mobility and Transport

- Ensure sustainable infrastructure
- Promote sustainable mobility of people and goods

6 Reduce Climate-Altering Emissions and Decarbonize the Economy

- Reduce energy consumption and increase energy efficiency
- Increase renewable energy production while avoiding or limiting impacts on cultural heritage and landscapes
- Reduce greenhouse gas emissions

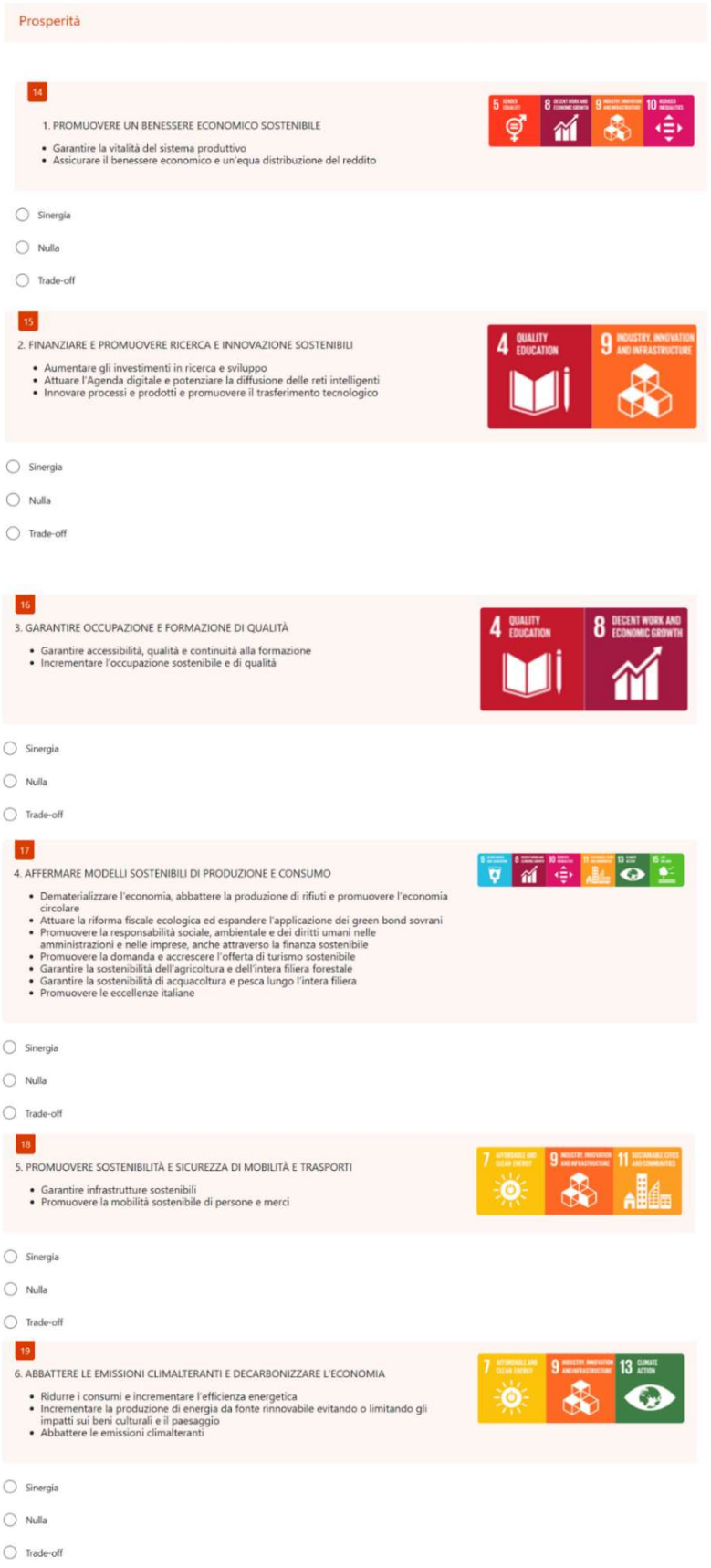


Figure 36: Screenshots from the questionnaire - Section 5

Section 6: Peace's Strategic Choices and National Strategic Objectives

1 Promote a Non-violent, Inclusive Society Respectful of Human Rights

- Prevent violence against women, children, and marginalized social groups, ensuring adequate assistance to victims
- Ensure reception of asylum-seeking migrants and inclusion of immigrants and ethnic and religious minorities
- Promote peace and disarmament policies consistent with human rights and climate justice

2 Eliminate All Forms of Discrimination

- Eliminate all forms of labor exploitation and guarantee workers' rights
- Ensure gender equality
- Combat all forms of discrimination and promote respect for diversity, equity, and inclusion

3 Ensure Legality and Justice

- Intensify the fight against crime
- Combat corruption and extortion within the public system
- Ensure efficiency and quality of the judicial and penitentiary system
- Promote representative institutions responsive to citizens' needs

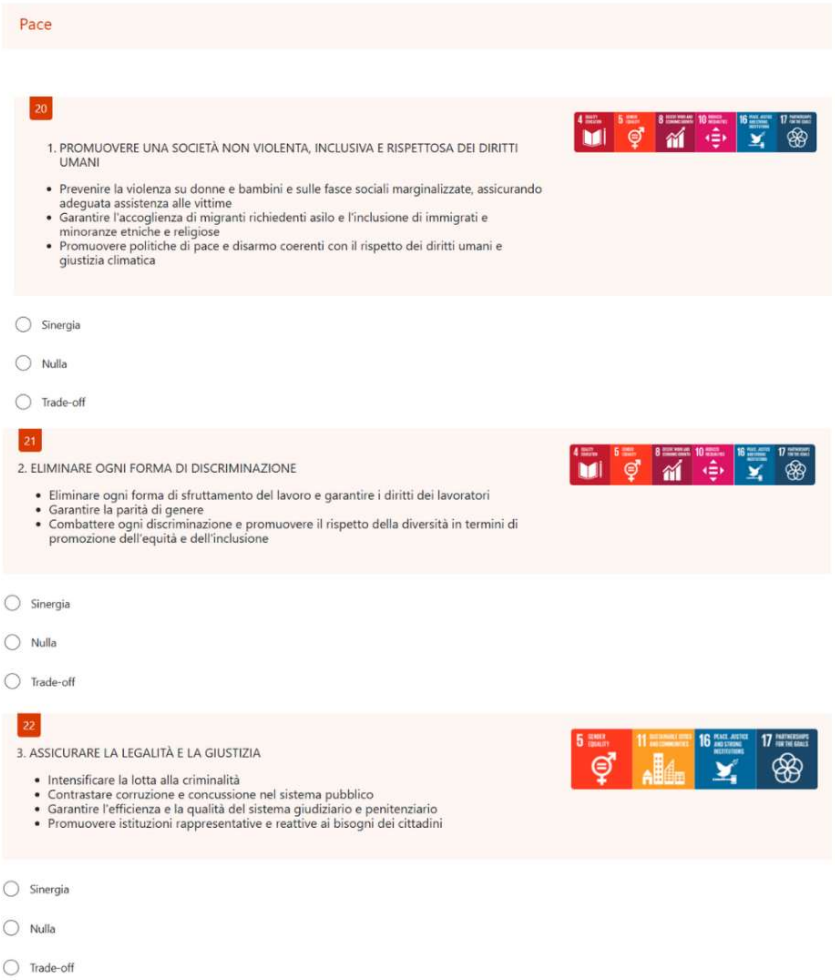


Figure 37: Screenshots from the questionnaire – Section 6

6.3 DATA ANALYSIS

6.3.1 Description of the Analysed Sample

The questionnaire received 89 answers out of 136 data sheets of technologies, corresponding to **65,4%**.

The analysed sample reflects the same division structure found in MATRICS, as pictured in Figure 28, although some technologies are missing from the responses. This indicates that most

of the sampled technologies come from TERIN division and therefore belong to the energy sector. As a result, SDGs 5,7, 11, and 13 are the ones most likely to be selected.

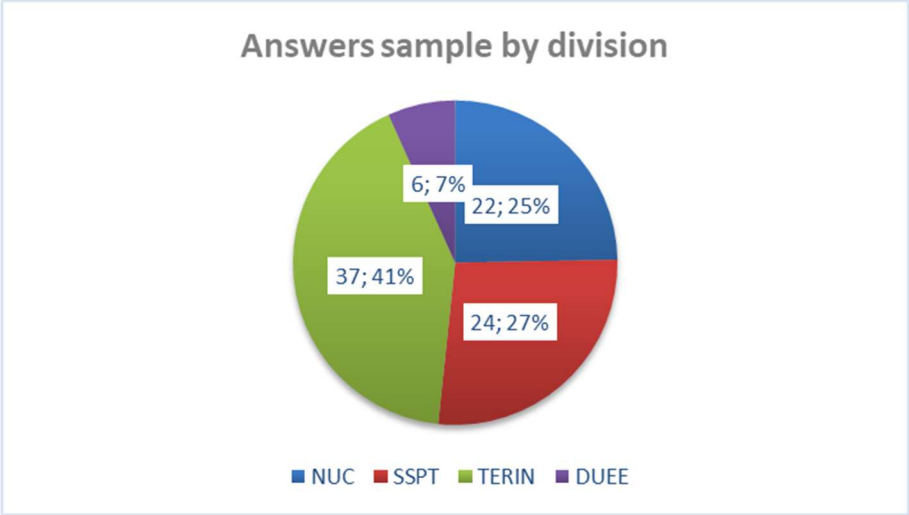


Figure 38: Distribution of received answers by division, personal elaboration

The distribution of verticals in the responses (Figure 39) confirms the predominance of the energy sector, while also highlighting the frequent presence of the environment and circular economy verticals. For this reason, SDG 12 is also expected to be very recurrent.

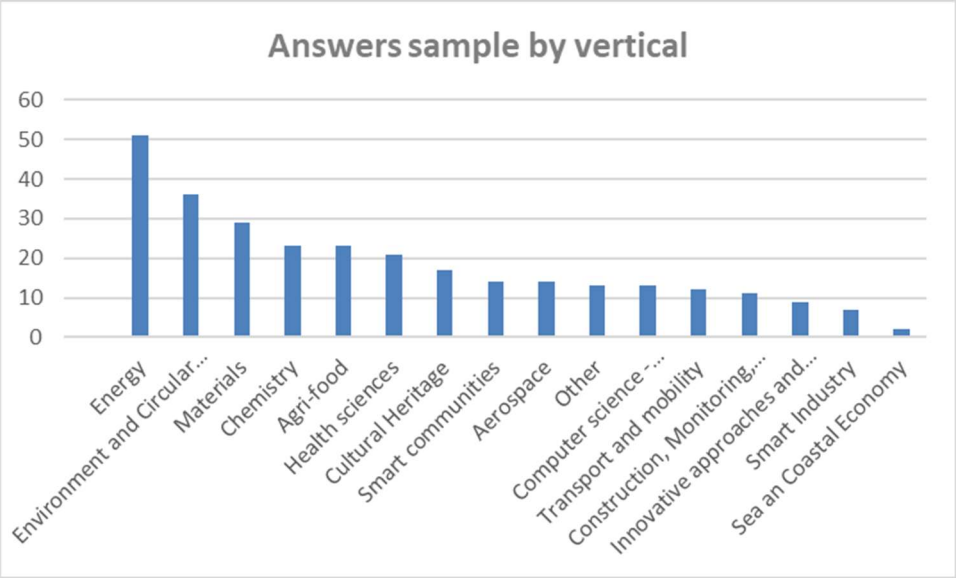


Figure 39: Distribution of received answers by vertical, personal elaboration

Considering these observations, let's now look at which goals were most frequently selected by the researchers. In the following Table 7 all the selections for each MATRICS data sheet are shown and then summarized in the graph of Figure 40.

Table 7: SDGs selected by the technology owners for each sampled technology

ID MATRICS	SDGs selected	ID MATRICS	SDGs selected
8518	9	8387	3,9
8580	9	8536	11,13
8601	7,13	8447	3,9
8639	1,2,3,4,8,9,10,11	9908	13,15
8400	9,12	8590	11
8570	9,12	8893	9
8576	3,6,9,15	9909	7
8390	3,7,8,11,12,13,16	8459	11
8440	3	8441	3
8405	9	9894	2,3,9,12
8511	3,7,12,15	8786	9,11
8619	6,7	8613	3,6,9,11,15
8620	7,11,12	8430	3,6
8656	1,2,9,12,13,15	8596	7
9903	7,12,13	8713	9,11,13
8493	11	8825	9
8643	7,9,11,12	8742	7,9,11,12,13
8428	3	8779	7,11
8521	9	8449	3
8422	7,12,13,14	8389	6,9,11,15
8820	2,3,12	8429	7
8632	7,9	8436	7
8659	9,13	8446	13
8662	7,9,11,13	8517	11
8382	3	9896	3
8381	7,9	8657	11
8636	7,8,9,11,12,13	8717	7,11,12
8637	7,12,13,17	8582	9,11
8496	11,12	8618	3,9,12,17
8501	11,12	8669	8
8437	3,7,9,12	8568	7,9,12,13
8599	7	8840	7,11
8746	12	8675	9
8414	7,9,11,12	8495	9,11,13
8488	6	9898	3,11,13,15
8624	2,12,13	8615	7,9
8584	7,12	8615	7,9,13
8734	12	8466	7,9,13
8577	12,15	8629	6,7,12,13,15
8646	9	8634	7,13
8661	3	8770	3,1
9900	3,7,9,11,12,13	8497	9,12
9902	7,9,11,12,13	8583	3,6,9,11,12
8585	3	8391	7,9,12

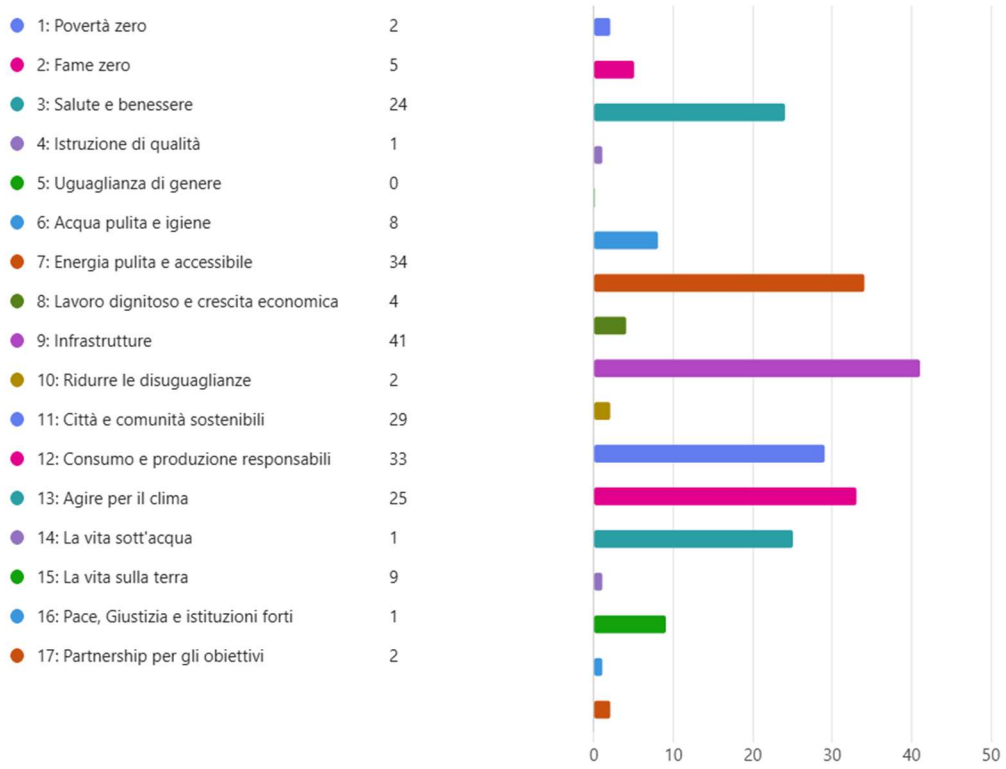


Figure 40: Answers analysis from "Indicate which SDGs of the 2030 Agenda the technology under development can potentially be associated with. (SDG 9 here considered only as "Infrastructures")"

The responses range widely, covering almost all the goals. Moreover, since the target users of the MATRICS database are companies and industrial stakeholders, the technologies included are those most closely related to production and energy aspects.

SDG 9 – Infrastructures – was the most selected Goal, followed by SDG 7 (Affordable and clean energy) and SDG 12 (Responsible consumption and production). These goals reflect the expectations based on the verticals and division distribution of the sample, and they also align with ENEA's mission.

SDGs 3,11 and 13 come after the top three. While SDGs 11 and 13 are still connected with the two main verticals pictured before, SDG 3 may be linked to many different verticals like Health Science but also Chemistry verticals.

The SDG 14 (Life below water) was one of the least selected, coherently with the least frequent vertical of the answer sample that is Sea and Coastal economy.

SDG 5 (Gender equality) was never selected, and this is maybe due to the more political approach to the subject that seems too far from the technological field. The same concept applies for the other least selected Goals such as 1 (Zero Hunger), 4 (Quality Education), 10

(Reduced Inequalities), 16 (Peace, Justice and Strong institutions), 17 (Partnerships for the Goals).

6.3.2 Environmental impact assessment

As explained in the questionnaire design the possible presence of quantitative impact analyses related to the technologies have been considered, as well as the MATRICS' strength on environmental impact cited in the analysis of MATRICS (5.3.1).

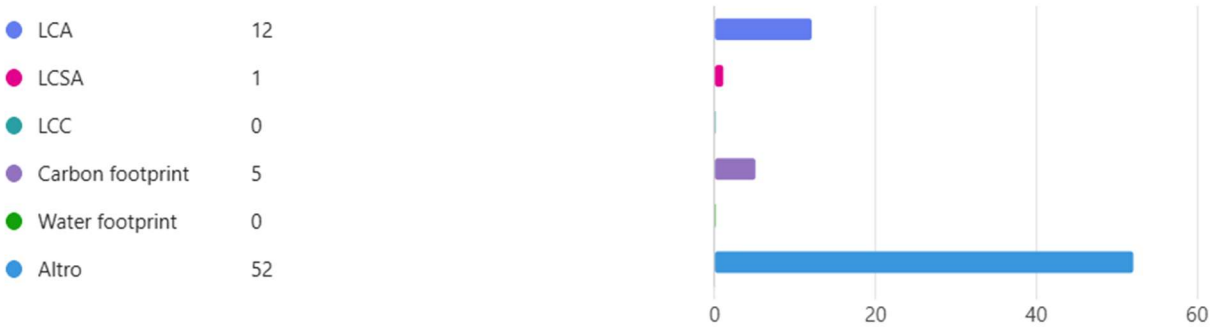


Figure 41: Answers analysis from "Has a sustainability assessment of the technology been carried out?"

The most selected option "other" contains 39 negative answers, meaning that 44.32 % of the technologies received in the questionnaire has not a quantitative sustainability impact assessment.

Figure 42: Answers analysis from "Was environmental impact selected as a strength of the technology for the MATRICS fact sheet?"

Surprisingly, environmental impact is considered a strength of the innovative technology only for the 36% of the technologies assessed.

6.3.3 NSDS strategic choices analysis

The National Sustainable Development Strategy explores how national SDGs can be achieved in a systemic way, and how it is possible to identify actions that take into account the multiple relationships existing between the different dimensions of sustainability, considered through the 5 Ps. In the following figures, a focus on the interlinkages emerging from the NSDS and its Strategic choices, among the 4 Ps.

Pillar	**People**
Strategic Choice	FIGHT POVERTY AND SOCIAL EXCLUSION, ELIMINATING TERRITORIAL GAPS
SDGs interlinkages	

Figure 43:Question 8 Synergies, No links, Trade-offs

Pillar	**People**
Strategic Choice	GUARANTEE THE CONDITIONS FOR THE DEVELOPMENT OF HUMAN POTENTIAL
SDGs interlinkages	

Figure 44: Question 9 Synergies, No links, Trade-offs

Pillar	People
Strategic Choice	PROMOTE HEALTH AND WELLBEING
SDGs interlinkages	

Figure 45: Question 10 Synergies, No links, Trade-offs

Only for this Strategic choice of People dimension, the most selected answer was “Synergy”. Indeed, this result is consistent with the observations previously made regarding SDGs with a more socio-political dimension.

Pillar	Planet
Strategic Choice	HALT THE LOSS OF BIODIVERSITY
SDGs interlinkages	

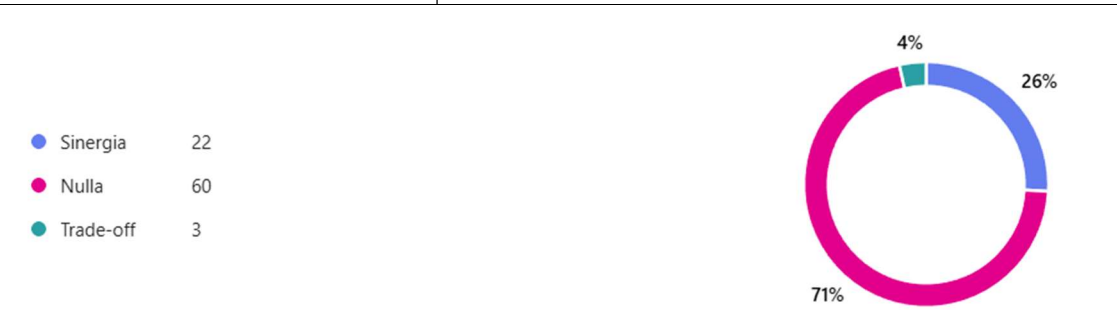


Figure 46: Question 11 Synergies, No links, Trade-offs

Pillar	Planet
Strategic Choice	ENSURE THE SUSTAINABLE MANAGEMENT OF NATURAL RESOURCES

SDGs interlinkages	

Figure 47: Question 12 Synergies, No links, Trade-offs

Only for this Strategic choice of Planet dimension, the most selected answer was “Synergy”, even though among the SDGs included with the choice there is SDG 14 that was among the least selected in the first question of this questionnaire (Figure 40).

Pillar	**Planet**
Strategic Choice	CREATE RESILIENT COMMUNITIES AND TERRITORIES, PROTECT LANDSCAPES AND CULTURAL HERITAGE
SDGs interlinkages	

Figure 48: Question 13 Synergies, No links, Trade-offs

Pillar	**Prosperity**
Strategic Choice	PROMOTE A SUSTAINABLE ECONOMIC WELLBEING
SDGs interlinkages	

Figure 49: Question 14 Synergies, No links, Trade-offs

Pillar	**Prosperity**
Strategic Choice	FUND AND PROMOTE SUSTAINABLE RESEARCH AND INNOVATION
SDGs interlinkages	

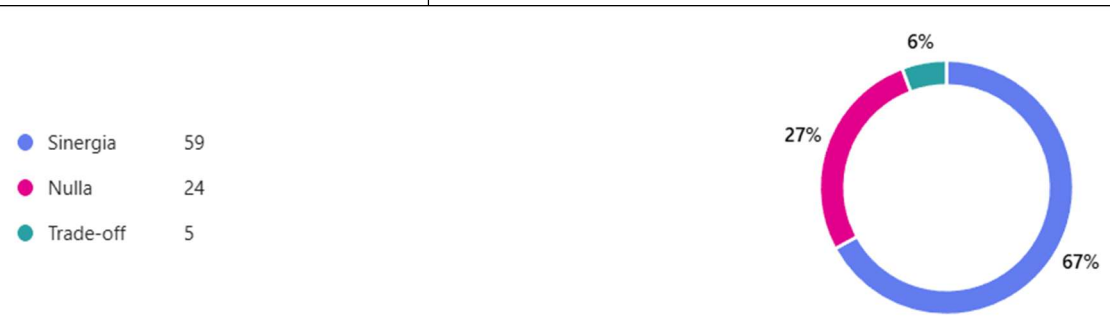


Figure 50: Question 15 Synergies, No links, Trade-offs

Pillar	**Prosperity**
Strategic Choice	ENSURE FULL EMPLOYMENT AND HIGH-QUALITY TRAINING
SDGs interlinkages	

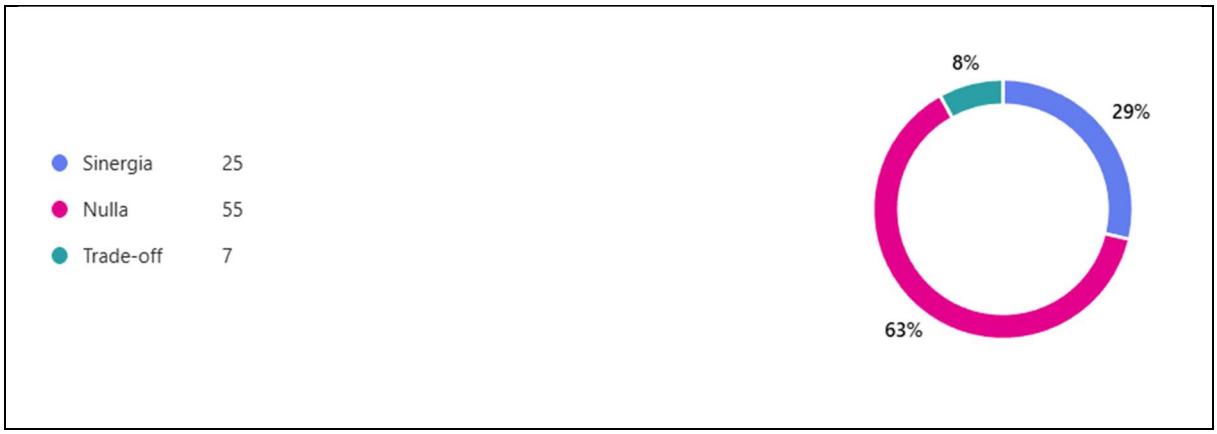


Figure 51: Question 16 Synergies, No links, Trade-offs

Pillar	**Prosperity**
Strategic Choice	ENSURE SUSTAINABLE PRODUCTION AND CONSUMPTION PATTERNS
SDGs interlinkages	

Figure 52: Question 17 Synergies, No links, Trade-offs

Pillar	**Prosperity**
Strategic Choice	PROMOTE SUSTAINABILITY AND SECURITY OF TRANSPORT AND MOBILITY
SDGs interlinkages	

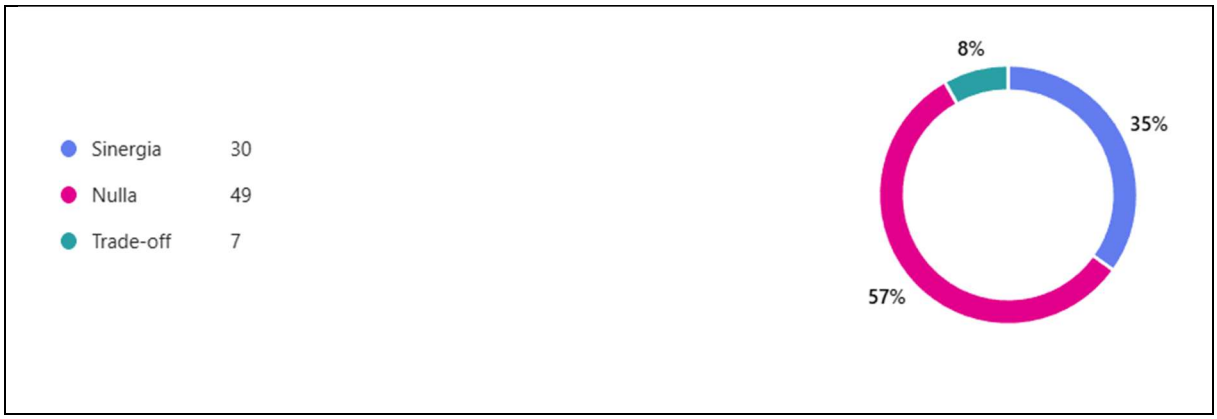


Figure 53: Question 18 Synergies, No links, Trade-offs

Pillar	**Prosperity**
Strategic Choice	DECARBONIZE THE ECONOMY
SDGs interlinkages	

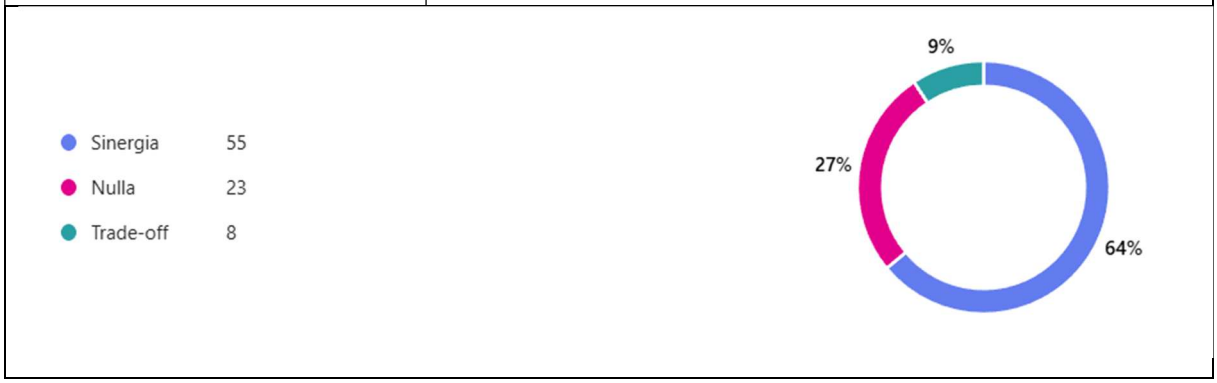


Figure 54: Question 19 Synergies, No links, Trade-offs

The Prosperity dimension encompasses many SDGs, and therefore the responses indicate a higher number of synergies compared to the other "Ps". Moreover, decarbonizing the economy is a core objective of ENEA, as is sustainable production and consumption, both of which are central elements of the Prosperity dimension.

The strategic choice "Fund and Promote Sustainable Research and Innovation" received the highest number of positive responses, precisely due to the nature of ENEA's research activities.

Energy and Infrastructure are SDGs that frequently recur within the Prosperity dimension, indicating again a strong connection with the verticals mentioned previously.

Pillar	**Peace**
Strategic Choice	PROMOTE A NON-VIOLENT, INCLUSIVE AND RESPECTFULL OF HUMAN RIGHTS SOCIETY

SDGs interlinkages	

Figure 55: Question 20 Synergies, No links, Trade-offs

Pillar	**Peace**
Strategic Choice	END DISCRIMINATION IN ALL ITS FORMS
SDGs interlinkages	

Figure 56: Question 21 Synergies, No links, Trade-offs

Pillar	**Peace**
Strategic Choice	ENSURE LEGALITY AND JUSTICE
SDGs interlinkages	

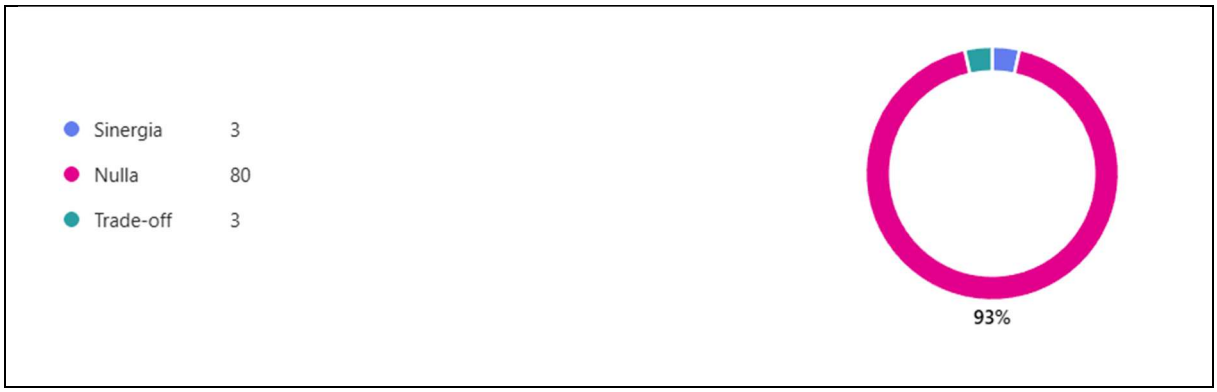


Figure 57: Question 22 Synergies, No links, Trade-offs

The responses for the Peace dimension further confirm that this aspect is perceived as overly socio-political and, as the majority of researchers selected “no links”, they struggle to identify a clear link with innovative technologies.

6.3.4 Summary of synergies and trade-offs with the NSDS

The following section presents a comparison of the different Strategic choices within each “P” (People, Planet, Prosperity, Peace), based on the number of MATRICS data sheets reporting synergies (in green) and trade-offs (in red).

Overall, synergies outweigh trade-offs across all Ps.

Numbers show that the majority of the technologies are concentrated in the Prosperity dimension, while Peace is the least involved. While records for People and Planet are comparable, with respectively “Promote health and well-being” and “Ensure the sustainable management of natural resources” as the Strategic choices with most of synergies, Peace is left behind with just a few positive responses.

Figure 58: ENEA's contribution to NSDS People

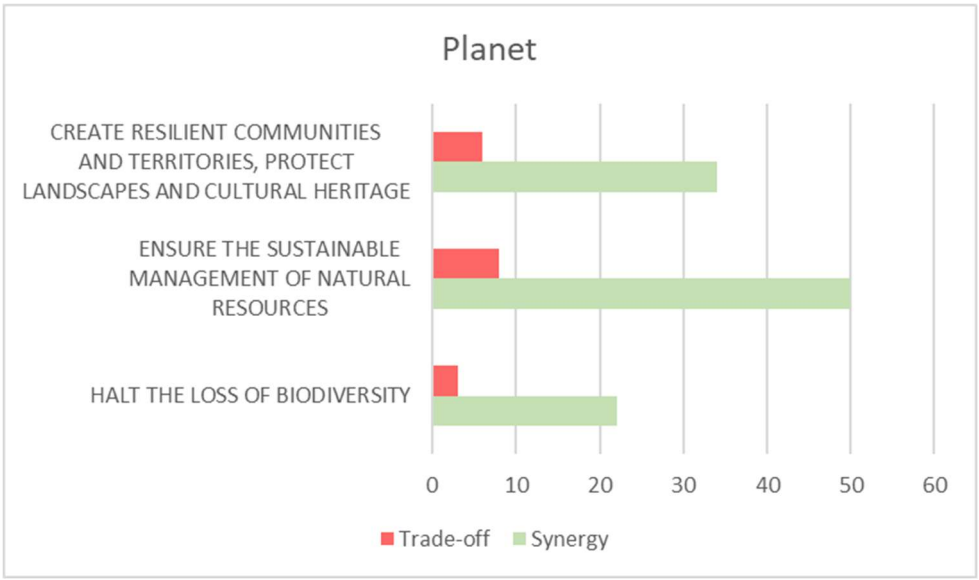


Figure 59: ENEA's contribution to NSDS Planet

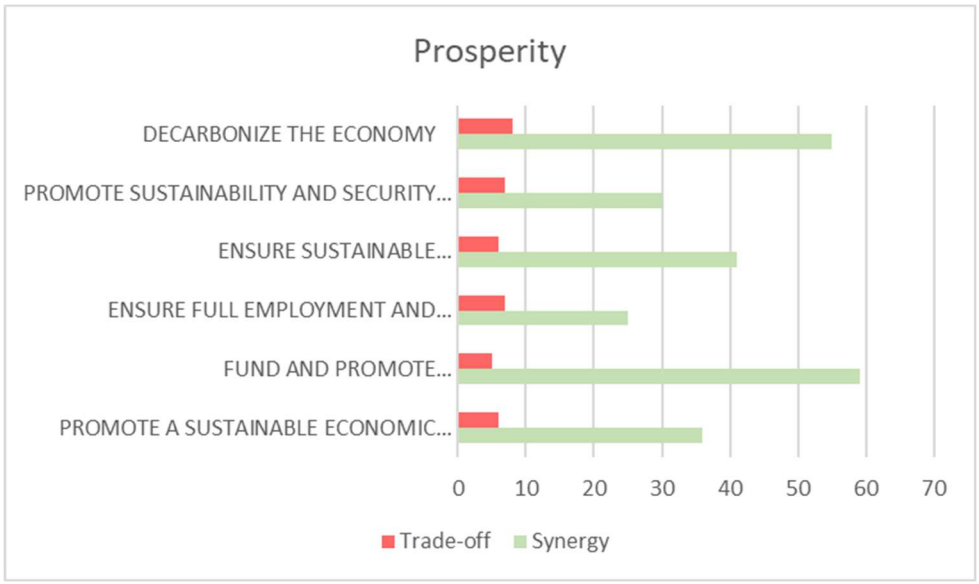


Figure 60: ENEA's contribution to NSDS Prosperity

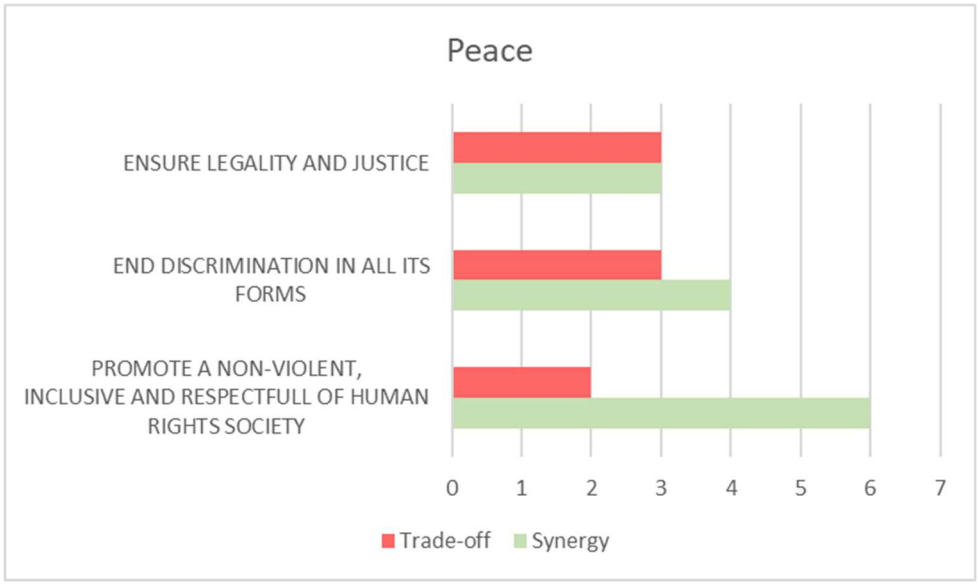


Figure 61: ENEA's contribution to NSDS Peace

Moreover, Peace it is found the only Strategic choice in which trade-offs equal synergies, and reasons have been already mentioned.

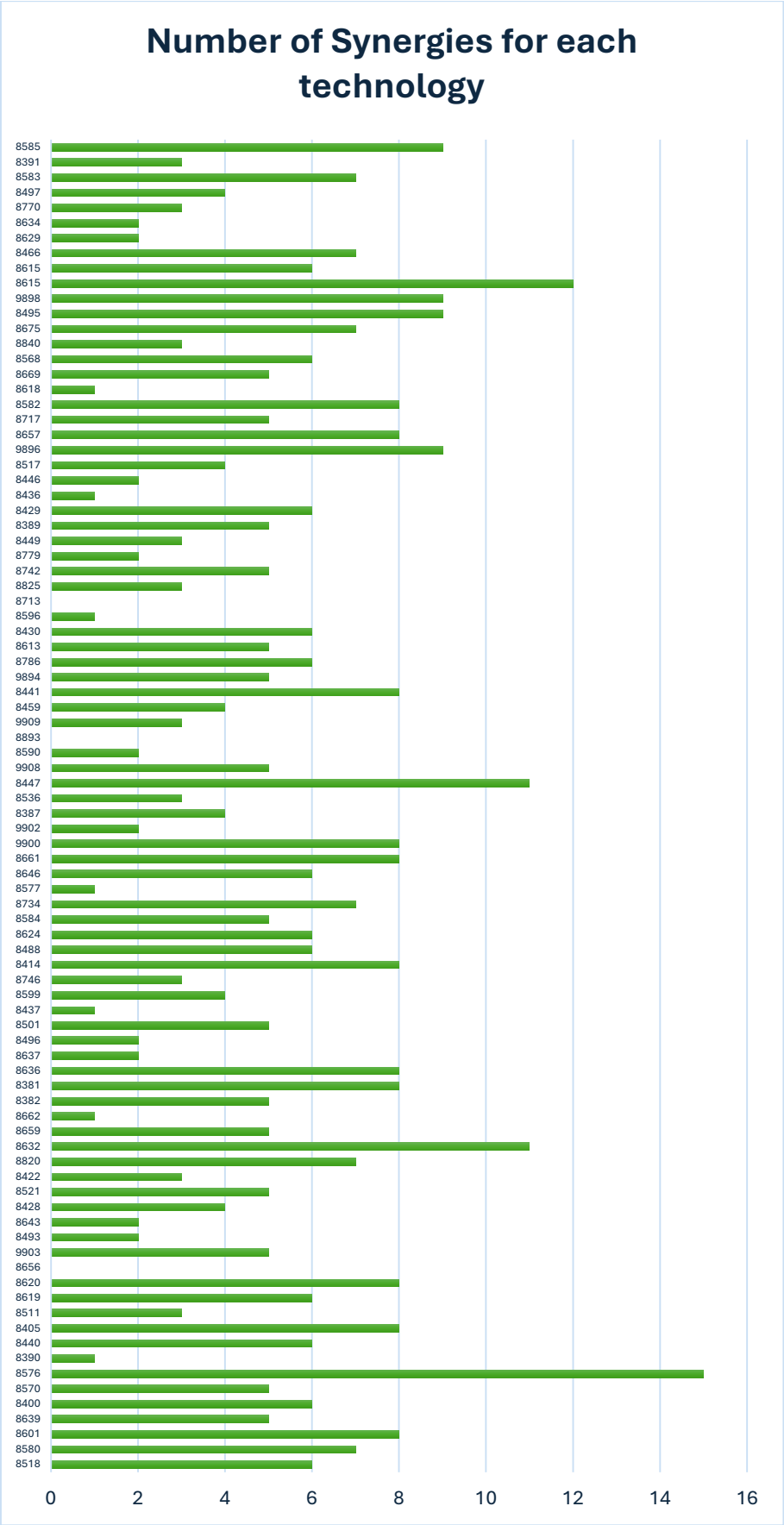


Figure 62: Frequency of Synergy Selections

With this graph in Figure 62 it is possible to see how synergies selection was very variable across the different technologies sampled.

The technology with the highest number of synergies, 15, is “Ionic liquid for electrochemical devices” with MATRICS ID 8585, which data sheet is showed in Figure 27 above. We may also see that some technologies don’t have any positive response, due to a lack of interconnection seen by the owners of those technologies.

6.3.5 Analysis of ENEA’s contribution to the SDGs

By elaborating the answers on the strategic choices, we may obtain synergies and trade-offs for each SDG.

As explained in the questionnaire design the Atlas for Cooperation is considered for the questionnaire. In fact, only the technologies included in the Atlas currently have SDGs already associated with them. In this case, only two out of the 89 technologies are already linked to an SDG, while the remaining 87 do not yet have any SDG interlinkages identified.

Figure 63: Answers analysis from “Is the technology also included in the ENEA's Atlas of Cooperation?”

This response confirms that innovation is a context-dependent concept and reinforces the idea discussed in the previous chapters (5.1.1) that an analysis of the SDGs within MATRICS can provide insights at a different scale—namely that of Italian companies.

Starting from the interlinkages table (Table 4) and the frequency of SDGs across the different strategic choices, it is possible to derive the contribution of ENEA technologies to each SDG in terms of trade-offs or synergies.

Table 8: Comparison SDGs selection and SDGs resulting from the questionnaire

ID MATRICS	SDGs selected	Synergies	Trade-offs
8518	9	4, 5, 7, 8, 9, 10, 11, 16, 17	
8580	9	2, 4, 6, 7, 8, 9, 11, 12, 13, 14, 15	
8601	7,13	1, 2, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16	4, 8

8639	1,2,3,4,8,9,10,11	1, 2, 3, 4, 5, 6, 8, 9, 10, 11, 15, 16, 17	
8400	9,12	2, 3, 4, 6, 8, 9, 11, 12, 13, 14, 15, 16	
8570	9,12	2, 3, 4, 6, 8, 9, 10, 11, 12, 13, 14, 15, 16	
8576	3,6,9,15	2, 3, 4, 6, 8, 9, 11, 12, 13, 14, 15, 16	
8390	3,7,8,11,12,13,16	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17	
8440	3	2, 3, 11, 16	7, 9, 13
8405	9	1, 2, 3, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16	
8511	3,7,12,15	2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16	
8619	6,7	5, 6, 7, 8, 9, 10, 11, 13, 15	
8620	7,11,12	1, 2, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16	2, 14, 15
8656	1,2,9,12,13,15	1, 2, 3, 4, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16	4, 5, 8, 9, 10
9903	7,12,13		2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16
8493	11	1, 2, 3, 4, 6, 7, 8, 9, 10, 11, 15, 16	4, 9
8643	7,9,11,12	4, 7, 9, 13	1, 2, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16
8428	3	2, 3, 4, 9, 11, 16	5, 8, 9, 10
8521	9	2, 3, 6, 7, 8, 9, 11, 12, 13, 14, 15, 16	
8422	7,12,13,14	2, 4, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15	
8820	2,3,12	1, 2, 3, 6, 8, 10, 11, 13, 15, 16	
8632	7,9	2, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15	
8659	9,13	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 13, 14, 15, 16, 17	2, 6, 11, 12, 13, 14, 15
8662	7,9,11,13	2, 4, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15	2, 3, 4, 7, 8, 9, 11, 16
8382	3	2, 3, 11, 16	
8381	7,9	2, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15	
8636	7,8,9,11,12,13	2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16	
8637	7,12,13,17	2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16	
8496	11,12	7, 9, 11, 13	
8501	11,12	7, 9, 11, 13	
8437	3,7,9,12	2, 3, 4, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16	
8599	7	7, 9, 13	
8746	12	2, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15	
8414	7,9,11,12	2, 5, 6, 8, 9, 10, 11, 12, 13, 14, 15	4, 7, 9, 13
8488	6	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17	
8624	2,12,13	1, 2, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16	
8584	7,12	2, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15	
8734	12	2, 4, 5, 6, 8, 9, 10, 11, 12, 13, 14, 15	
8577	12,15	2, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15	
8646	9	2, 3, 11, 16	4, 5, 6, 7, 8, 9, 10, 11, 13, 15, 16, 17
8661	3	1, 2, 3, 4, 6, 8, 9, 10, 11, 12, 13, 14, 15, 16	6, 7, 8, 9, 10, 11, 13, 15
9900	3,7,9,11,12,13	2, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15	1, 2, 3, 4, 6, 8, 10, 11, 15, 16
9902	7,9,11,12,13	2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16	8, 11, 15
8387	3,9	2, 4, 6, 9, 11, 12, 13, 14, 15	
8536	11,13	2, 3, 6, 7, 9, 11, 12, 13, 14, 15, 16	
8447	3,9	2, 3, 4, 7, 9, 11, 13, 16	
9908	13,15	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16	
8590	11	2, 3, 4, 7, 8, 9, 11, 13, 15, 16	7, 9, 11

8893	9	2, 3, 6, 11, 12, 13, 14, 15, 16	
9909	7		
8459	11	4, 5, 7, 8, 9, 10, 13	
8441	3	2, 3, 4, 5, 8, 9, 10, 11, 16	4, 5, 8, 10, 16, 17
9894	2,3,9,12	1, 2, 3, 4, 5, 6, 8, 9, 10, 11, 12, 13, 14, 15, 16	7, 9, 13
8786	9,11	4, 6, 7, 8, 9, 10, 11, 13, 15	2, 3, 4, 6, 8, 11, 12, 13, 14, 15, 16
8613	3,6,9,11,15	2, 3, 4, 6, 8, 9, 10, 11, 12, 13, 14, 15, 16	
8430	3,6	1, 2, 3, 5, 6, 8, 9, 10, 11, 12, 13, 14, 15, 16	7, 9, 13
8596	7	2, 4, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15	
8713	9,11,13	4, 9	2, 6, 7, 9, 11, 12, 13, 14, 15
8825	9		
8742	7,9,11,12,13	2, 6, 7, 9, 11, 12, 13, 14, 15	
8779	7,11	1, 2, 4, 5, 6, 7, 8, 9, 10, 11, 13, 16	
8449	3	2, 3, 4, 9, 11, 16	
8389	6,9,11,15	1, 2, 4, 6, 7, 9, 10, 11, 13, 16	2, 6, 11, 12, 13, 14, 15
8429	7	2, 3, 4, 7, 8, 9, 11, 13, 15, 16	4, 8
8436	7	4, 5, 6, 7, 8, 9, 10, 11, 13, 15	2, 3, 4, 5, 6, 8, 10, 11, 12, 13, 14, 15, 16, 17
8446	13	7, 9, 13	7, 9, 11
8517	11	4, 7, 9, 13	
9896	3	2, 3, 4, 5, 8, 9, 10, 11, 15, 16	
8657	11	1, 2, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17	
8717	7,11,12	1, 2, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16	
8582	9,11	2, 4, 6, 7, 8, 9, 11, 12, 13, 14, 15	
8618	3,9,12,17	1, 2, 3, 4, 5, 6, 8, 9, 10, 11, 12, 13, 14, 15, 16	
8669	8	7, 9, 11	4, 5, 7, 8, 9, 10, 11, 13, 16, 17
8568	7,9,12,13	4, 5, 6, 7, 8, 9, 10, 11, 13, 15	
8840	7,11	1, 2, 3, 4, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16	4, 5, 6, 7, 8, 9, 10, 11, 13, 15
8675	9	2, 3, 5, 6, 8, 9, 10, 11, 13, 15, 16	4, 8, 9, 11, 15
8495	9,11,13	2, 3, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16	
9898	3,11,13,15	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17	
8615	7,9	4, 5, 6, 7, 8, 9, 10, 11, 13, 15, 16, 17	
8615	7,9,13	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17	
8466	7,9,13	2, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15	
8629	6,7,12,13,15	2, 3, 4, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16	
8634	7,13	4, 7, 9, 13	
8770	3,1	2, 3, 4, 9, 11, 16	
8497	9,12	4, 7, 9, 11, 13	2, 5, 6, 8, 9, 10, 11, 12, 13, 14, 15
8583	3,6,9,11,12	2, 3, 4, 6, 7, 8, 9, 10, 11, 13, 15, 16	
8391	7,9,12	2, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15	
8585	3	2, 3, 4, 6, 9, 11, 12, 13, 14, 15, 16	
8714	7,9	2, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15	1, 2, 3, 4, 6, 8, 10, 11, 16

It is evident that the selection by the researcher loses a wider range of possible interlinkages with SDGs. The result that emerges from the analysis of the questionnaire is the increment of synergies in the first place and secondly, of trade-offs that were not even considered before.

We may now take some technologies as example of this important result.

Table 9: Selection of three data sheets as example

ID MATRICS	SDGs selected	Synergies resulting
8390	3,7,8,11,12,13,16	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17
8646	9	2, 3, 11, 16
8585	3	2, 3, 4, 6, 9, 11, 12, 13, 14, 15, 16

In the first observed technology with MATRICS ID 8390, the owner has selected seven SDGs, one of the wider selections among the answers collected. These SDGs are still there in the results, but the synergies found by the questionnaire have increased the interlinkages to the entire set of 17 SDGs. This is also the technology cited in the section “Summary of synergies and trade-offs” as the technology having the most of synergies. The second technology with MATRICS ID 8646 has only one SDG selected that is SDG 9. Results show 4 interlinkages with different SDGs and SDG 9 is not even recalled. The third technology with MATRICS ID 8585 has again one selection of SDG 3, while results show interlinkages with 11 SDGs with the one previously selected here appearing in the results. This increase in the number of SDGs involved from the selection to the results is further showed in the next figure.

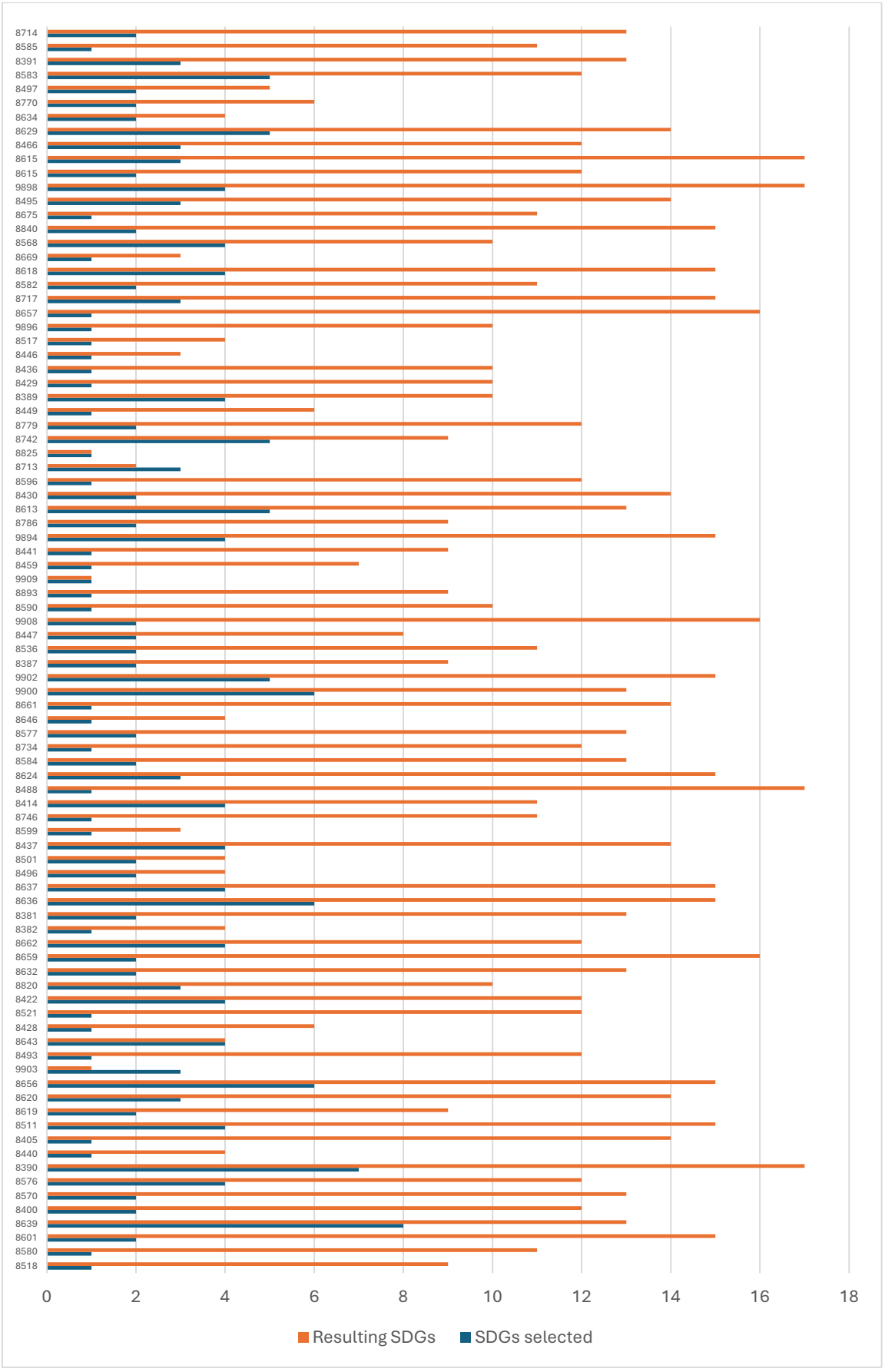


Figure 64:Comparison between the number of selected SDGs and resulting SDGs

It is now possible to carry out an overall assessment of the potential contribution of ENEA's technological portfolio to the SDGs, that is, the outcomes that may be achieved at the end of the technology transfer process, once the technologies move beyond the laboratory and are applied in an industrial context. The following graph (Figure 65) presents the total synergies and trade-offs associated with each SDG.

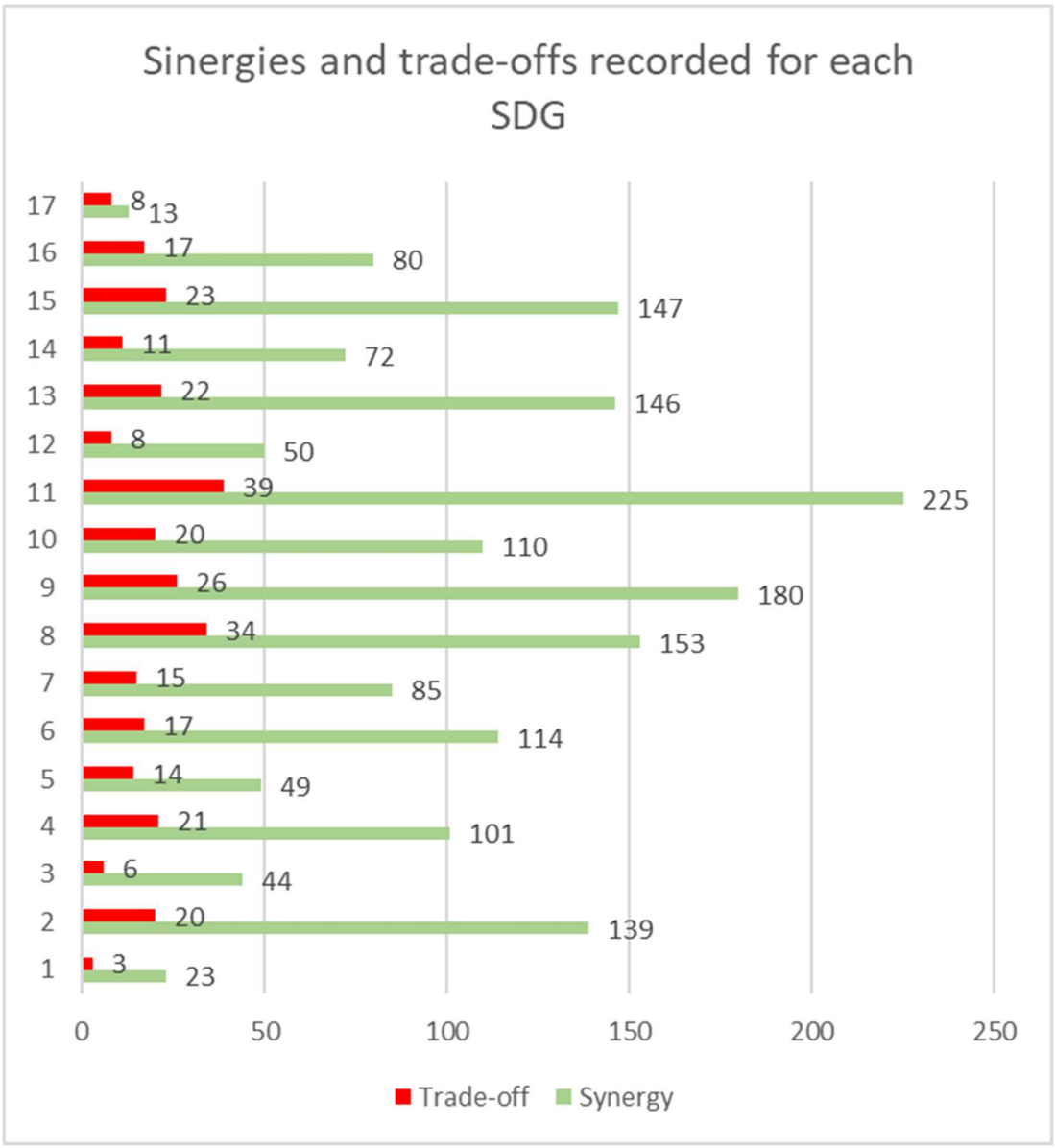


Figure 65: Synergies and trade-offs for each SDG resulting from the questionnaire

There are more occurrences than responses due to the structure of the strategic choices, which involve multiple SDGs. For example, SDG 8 shows 153 synergies and 34 trade-offs, while SDG 14 records 72 synergies and 11 trade-offs.

In particular, the sample of 89 technologies shows 225 synergies with SDG 11, largely due to its recurrence across the strategic choices, making it the SDG with the highest number of synergies as well as the highest number of trade-offs. On the contrary, results show that SDG 17 is the last in terms of synergies (13) while SDG 1 for trade-offs (3). The rest of the Goals stay in the synergies range from 23 to 180, while for trade-offs range from 6 to 34.

The results obtained (Figure 65) show a different situation compared to the first set of responses shown in Figure 40. Differences may be highlighted by comparing the following graphs in Figures 66 and 67.

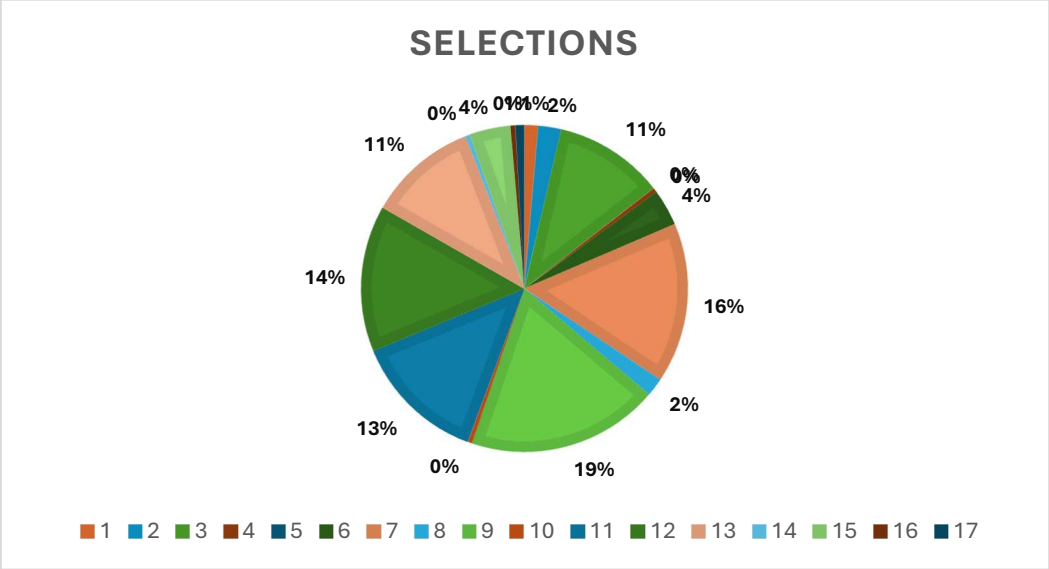


Figure 66: SDGs selected in percentage

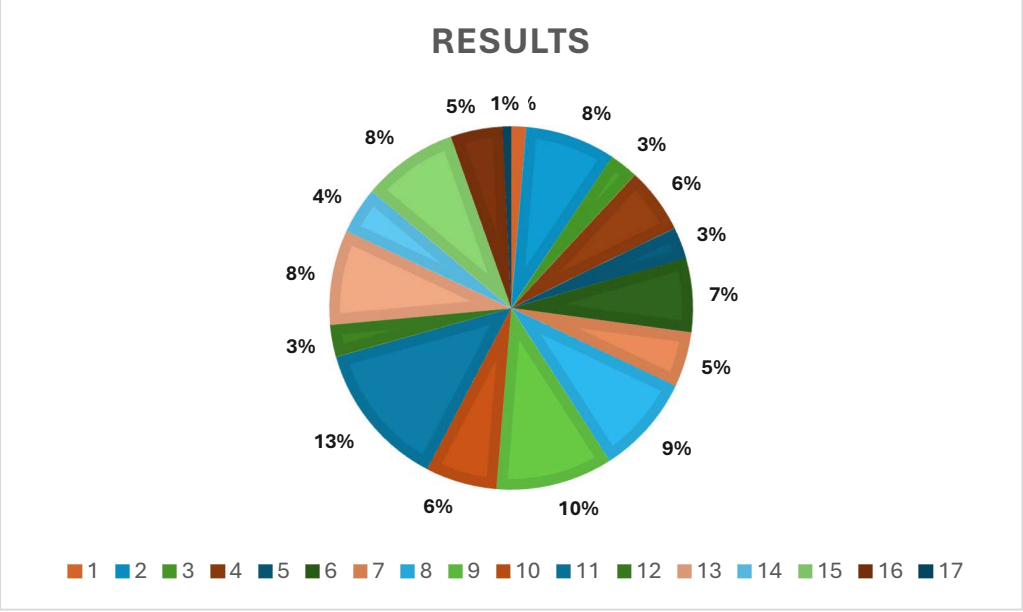


Figure 67: SDGs emerging from the results in percentage

In the first place, the most selected SDG was previously the 9 while results now picture SDG 11 as the most relevant.

Secondly, SDG 14 results having average synergies (72) and trad-offs (11) while at first it was almost not selected. Also, SDG 5 that was before the only SDGs with zero selections, show in the results some synergies (49) and trade-offs (14), even if remaining among the last SDGs.

Another important result is found with SDG 12 that was at first in the top three SDGs selected while now it is among the last ones, with 50 synergies (SDG 14 for example has 72 synergies). Similarly for SDG 7 with its 85 synergies found.

This result may appear in contrast with the description of verticals involved as pictured before, but SDGs 7 and 12 are in fact not highly recurrent in the NSDS, respectively 4 and 3 times. Interestingly, by using the NSDS as methodology the important result that is obtained is a more balanced SDG distribution among all the Ps, while in the first selection the weighting of the different SDGs was shifted to the Energy and Environment verticals characterizing ENEA'S technological offer.

The above-mentioned charts do not include the values related to the third "nothing" option, which corresponds to cases in which researchers do not identify any connection between their technology and the selected Strategic choice.

An analysis of the frequency of "nothing" responses for each SDG reveals that this option is the most frequently selected, exceeding both synergies and trade-offs. On the one hand, this may reflect the fact that researchers often maintain a narrow perspective focused primarily on the technical aspects of their work, with limited consideration of the broader social and environmental impacts that may derive from it. On the other hand, identifying trade-offs may be more complex than recognizing synergies, particularly while a technology remains at the laboratory scale. In the next figure the "nothing" selection is pictured for each SDG.

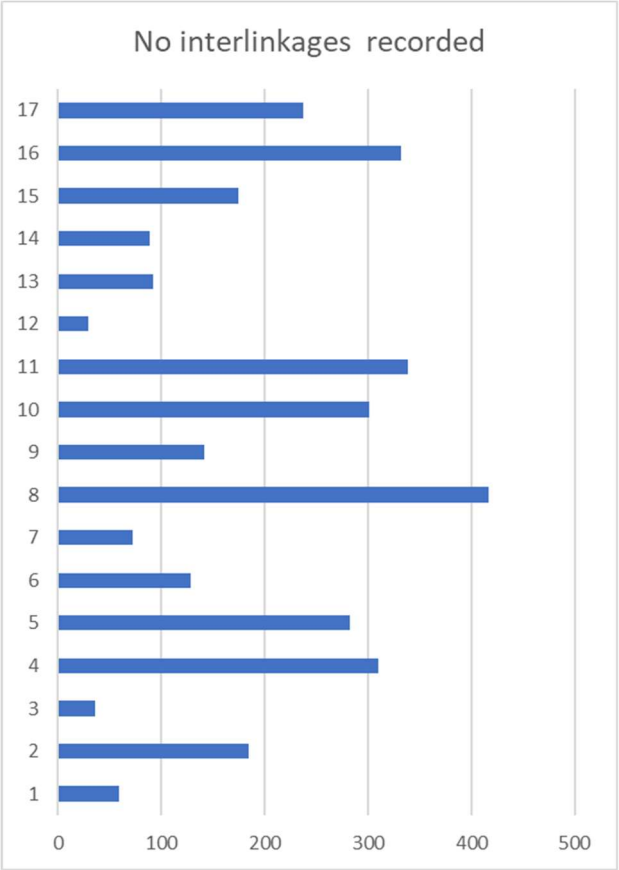


Figure 68: Lack of any link with the SDG

6.4 DISCUSSION AND CONCLUSIONS

The analysis presented in the section "Description of the Analysed Sample" (Figures 38 and 39) shows a good degree of consistency between the distribution of technological verticals, the missions of the ENEA departments, and the SDGs selected for each technology. This alignment suggests that the technologies included in the MATRICS database broadly reflect the institutional priorities and research areas of the Agency.

However, the "Strengths" section of MATRICS does not always sufficiently highlight the full potential of the technologies. In many cases, technologies have not undergone a quantitative environmental impact assessment, such as a Life Cycle Assessment (LCA), water footprint, or carbon footprint analysis, which would allow for a more comprehensive evaluation of their sustainability impacts.

The results of the questionnaire indicate that the technologies tend to generate more synergies than trade-offs across the various SDGs. In particular, within the framework of the NSDS, synergies significantly outweigh trade-offs in the Prosperity dimension, whereas the difference is less pronounced in the Peace area.

At the same time, the section "ENEA's Contribution to the SDGs" reveals new dynamics. Some synergies emerge with SDGs that had not been previously selected by researchers, while other SDGs initially considered among the most relevant appear to generate fewer synergies in the final assessment. This finding highlights an important limitation in relying exclusively on the strategic framework to identify interlinkages with certain SDGs that may appear less frequently in the Strategy but are highly relevant in the ENEA context, such as SDG 7 and SDG 12.

These results are influenced by the use of the National Strategy, which proposes a systemic perspective that goes beyond purely technological and environmental aspects. On the one hand, the researchers' perspective did not cover all the strategic choices or all the dimensions of the Strategy; therefore, it is expected that a different weighting emerges for the SDGs most closely related to ENEA's mission. On the other hand, this analysis has made it possible to highlight contributions also to those SDGs that are not directly linked to strictly technological domains but rather to broader socio-economic and political challenges.

Another relevant aspect concerns the frequent selection of the response option "nothing," which indicates that researchers did not perceive a connection between their technology and specific strategic choices. In fact, "nothing" emerged as the most frequently selected response. This may reflect the fact that researchers often maintain a limited view on their technologies, having consideration of the broader social and environmental impacts that may derive from their products.

A particularly illustrative example concerns SDG 5. This goal was not selected at all by researchers in the initial stage; however, the final evaluation revealed the presence of both synergies and trade-offs. Although these remain among the least frequent, their presence nonetheless demonstrates that relevant interconnections may exist even when they are not immediately recognized by technology developers.

The identification and application of the SDG interlinkages methodology proposed by the National Strategy proved particularly valuable. This framework can serve as a useful tool to guide researchers in assessing how their technologies may contribute to the 2030 Agenda, not

only in terms of innovation and economic growth but also with regard to broader social and environmental dimensions.

At the same time, the results must be interpreted in light of some limitations of the study. The sample size is relatively limited, and the analysis focuses exclusively on technologies. Moreover, technologies related to certain verticals—particularly energy—are more numerous within the sample and therefore have a greater potential to contribute to the advancement of the 2030 Agenda.

Finally, the thesis proposes a qualitative assessment addressed to MATRICS technologies owners against NSDS strategic choices with ‘synergy / neutral / trade-off’ coding.

A quantitative analysis would represent the next step in the process. This would involve calculating the indicators associated with the SDGs in order to provide a measurable acceleration to the 2030 Agenda. However, such an effort depends on the institution’s strategic position, as it requires significant advancements in the approach to innovative technologies and a heightened awareness of the SDGs among researchers.

7 CONCLUSION

This thesis has explored the relationship between innovation, technology transfer, and the advancement of the Sustainable Development Goals, moving from the conceptual framework of the SDGs to the qualitative analysis of ENEA's innovative technologies.

After conducting an in-depth literature review and analysing the answers given by ENEA's researchers, it is now possible to return to the research questions and attempt to provide a comprehensive answer.

In the first place, this work investigates the role of innovation in advancing sustainable development, with particular focus on SDG 9 and its interconnections with other Sustainable Development Goals.

The thesis frames innovation as a systemic lever that accelerates progress across the economic, social, and environmental pillars of sustainable development. The analytical lens adopted in Chapter 3 show that innovation differs from eco-efficiency by embedding long-term value creation and systems thinking into firms' strategies, cultures, and inter-organizational networks. SDG 9 (Industry, Innovation and Infrastructure) is treated as the backbone that enables other goals by strengthening research capacity (Target 9.5), promoting sustainable industrial processes (9.4), and supporting domestic technology development and diversification (9.b). Also, it documents the recent global trends in R&D intensity and researcher density and, for Italy, mixed performance with advances in decarbonization and innovation activity, alongside lags in ICT employment. The thesis synthesizes evidence that SDG 9 targets, especially 9.4, 9.5, and 9.b, exhibit predominantly synergistic and often prerequisite relationships with many other SDGs, while trade-offs concentrate around 9.2 when industrial expansion is not aligned with environmental safeguards. Positive interactions are strongest with SDGs 7 (Energy), 8 (Economic growth), and 11 (Sustainable cities), whereas potential tensions arise with SDG 15 (Terrestrial ecosystems). Unfortunately, a methodological approach to determine interlinkages is lacking in scientific literature, meaning that these interactions are strongly context-dependent and difficult to quantitatively assess.

At national level, the Italian National Sustainable Development Strategy operationalizes interlinkages by clustering objectives into 15 National Strategic Choices across the 5Ps. Within 'Prosperity', SDG 9 recurs in four strategic choices: fund and promote sustainable research and innovation; sustainable economic wellbeing; sustainability and security of mobility;

decarbonizing the economy, making innovation a cross-cutting policy vector. The case study later in the thesis confirms that, when researchers assess technologies through an interlinkage lens, synergies with SDG 11, 5 and 14 frequently surface, even where technology owners did not initially select these goals, underscoring that innovation's impacts are broader than perceived in laboratory-centric viewpoints.

The analysis of innovation potential proposed by ENEA, based on the sample of technology offerings, confirms a higher prevalence of synergies with SDG 11 and SDG 8, while for trade-offs, SDG 15 continues to rank among the top four.

The second question concerns how technology transfer can act as a key enabler of sustainable innovation and contribute to the achievement of the objectives of the 2030 Agenda.

Chapter 4 illustrates technology transfer as a relational, multi-channel process moving beyond a linear lab-to-market model toward knowledge exchange and co-creation with firms and public administrations. Effective TT depends on robust intellectual property management, intermediary capabilities (TTO/KTOs), and staged finance (from PoC grants to venture capital). The thesis highlights Italy's situation with STEM publications rates that don't match patenting activities and structural bottlenecks caused by low R&D intensity, smaller TTOs, and fragmented revenues flow. Technology transfer operationalizes SDG 9 by: (i) upgrading industrial processes and infrastructures (9.4), (ii) expanding R&D capacity and spillovers to firms (9.5), and (iii) supporting domestic technology development (9.b).

Through interlinkages, these mechanisms propagate benefits to SDGs 1 (No Poverty), 7 (Clean energy), 8 (Economic growth), 12 (Responsible production), while requiring explicit governance to mitigate trade-offs with SDGs 14 and 15 in resource-intensive applications. The thesis identifies several key principles: align technology transfer schedules with strategic verticals such as energy and the circular economy, which have strong links with the SDGs; promote partnerships through open innovation and Knowledge Exchange to better identify industrial needs; and integrate SDG interlinkage analysis to identify synergies and manage trade-offs from the early stages.

An accurate analysis is essential, as researchers or technology owners may miss certain interconnections among the SDGs. At the same time, integrating SDG references into technological offerings represents an opportunity to enhance the impact of innovative technologies and increase their attractiveness to companies that are increasingly interested in investing in solutions that contribute to the achievement of the 2030 Agenda.

The third and last question was about how ENEA's technology transfer outputs can contribute to the achievement of the Sustainable Development Goals and how can that contribution be assessed.

ENEA's Technology Transfer activities coordinate a portfolio of tools with MATRICS catalogue at the core. They translate research into technologies, facilities, and services offered to private organizations and public bodies. Complementary outreach includes the Atlas for Development Cooperation, which documents SDG-oriented projects in developing contexts. The thesis conducts a structured survey of technology owners covering 89 technologies (65.4% response rate) across strategic verticals, especially energy and environment and circular economy. Two headline results emerge: (i) interlinkage mapping reveals predominant synergies with SDGs 11, 9, and 8, and (ii) "no links" responses are frequent, suggesting under-recognition of broader social-environmental linkages by technology owners.

Although ENEA's researchers perceive would suggest the primacy of SDGs 7, 9, and 12, the framing of the National Sustainable Development Strategy used in the questionnaire assigns a high recurrence to SDG 11 across several strategic choices. As a result, this SDG is statistically amplified in the aggregated analysis, showing a higher number of observed synergies. This helps explain the apparent discrepancy between ENEA's vertical specialization and the distribution of SDG interlinkage counts.

More broadly, the National Strategy represents a useful framework for highlighting connections among the SDGs, helping to broaden the perspective on potential benefits beyond a purely market-oriented analysis and towards a more comprehensive assessment of sustainability impacts across its three pillars. However, the strategic choices tend to concentrate on certain SDGs that recur across different dimensions of the Strategy, while other SDGs - sometimes more closely related to the technological verticals on which ENEA operates - appear less frequently.

This work shows, through the analysis of SDG interlinkages, that innovative technologies may generate potential benefits for SDGs that are not directly related to STEM fields. This aspect is not usually considered in assessments of the benefits and market potential of innovative technologies. This thesis has therefore helped to test, through the case study, a methodology for the systemic analysis of interlinkages between technology transfer and the SDGs as Goals for sustainability in all its levels.

While the present analysis is qualitative, future research could complement it with a quantitative assessment based on the specific targets of the SDGs that appear most frequently.

An open challenge remains: moving beyond a mono-disciplinary approach and embracing a transdisciplinary perspective, which is essential for achieving sustainability. In this process, collaboration with industry remains fundamental, as it enables the practical application and scaling of innovation, allowing research results to generate tangible impacts in real economic and societal contexts. However, the next step is to move beyond the laboratory and evaluate sustainability not only in terms of environmental impacts but also in relation to social-political and economic outcomes.

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9 LIST OF FIGURES AND TABLES

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