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Foresight on Demand (FoD)

Futures of Green Skills and Jobs in Europe in 2050: Scenario and Policy Implications

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December 15, 2023

Futures4Europe Policy Brief 6/2023

Funded by
the European Union

The brief is the result of one of eight Deep Dive Foresight Studies performed in the frame of the 'European R&I Foresight and Public Engagement for Horizon Europe' project, conducted by the 'Foresight on Demand' consortium for the European Commission. During the fall of 2023, an expert team identified factors of change and met in four workshops to build scenarios and derive policy implications. Other experts from national and EU public administration have also contributed to this report in various ways, through various channels. The authors would like to thank the external participants in the two scenario workshops and separate policy and dissemination workshops. The participants helped develop and elaborate on each of the four scenarios depicted in this report, as well as the policy implications of the individual scenarios. The process was developed in close collaboration with Nikolaos Kastrinos from the European Commission and further supported by discussions in the Commission's internal Horizon Europe Foresight Network. However, the final scenario narratives and all other text in this report are the responsibility of the authors only.

[1] Terms of use checked 22 October 2023 (latest updated March 14, 2023), see https://openai.com/policies/terms-of-use.

Executive Summary

Climate change and environmental degradation are an existential threat to the European Union and to the world. As a response, among other things, the European Green Deal aims to make Europe climate-neutral by 2050, boost the economy through green technology, create sustainable industry and transport, and cut pollution. The transition towards greener and more sustainable economies is a game changer in the EU labour market alongside digitalisation and automation. Skill needs will change with impacts far beyond the key occupations driving them, affecting all economic sectors.

Europe needs to promote and support green employment, address the skilling and reskilling of workers, and anticipate changes in workplaces of the future. In order to get a better grasp on potential future outcomes, and better anticipate their potential policy implications, a foresight Deep Dive has been carried out. The Deep Dive uses a broad conceptualization of skills that encompasses the full palette from scientific and engineering skills to vocational and crafts-like skills. All are needed in the green labour market, although the scenario-led focus here for the most part is on skills of vocational professions. This policy brief presents the main findings.

A set of four different scenarios for the futures of green skills and jobs in Europe in 2050 were crafted:

Scenario A: Green technology-intensive Europe: Struggling to fill all the green jobs
The European Union has advanced in a green transition across society and has gained global leadership in green technologies, resulting from aligned efforts. The EU is exporting the accumulated green knowhow and technologies and has become an engine for leading the world on a transition path towards a greener planet. Although past emissions continue to heat the globe, the world has avoided reaching major tipping points and the climate is gradually recovering. Europe is the global leader in the development and deployment of climate change mitigation technologies which, among others, reduce greenhouse gas emissions, generate renewable energy, and provide sustainable food production. Europe shows the way in the production of clean energy and its distribution to homes, businesses, and industries. Energy consumption is supplied by renewable energy sources (solar, wind, hydroelectric, and geothermal power) and nuclear energy. Europe is also excelling in climate change adaptation technologies that protect citizens against frequent, extreme, and severe weather conditions, such as heatwaves, floods, hurricanes, and forest fires. However, Europe has experienced a demographic shift. The population has aged and the total population has shrunk. Consequently, there is a low offer of labour, and specifically there is a low offer of green skilled workers. Job offers in renewable energy technology, green construction and sustainable urban planning are hard to fill.

Scenario B: Apocalypse Soon: Fighting skills mismatches in a degraded environment
After failed climate policy efforts, a sharp deterioration of the climate and the multiplication of extreme natural-related events, the environment is in a critical state in Europe and globally. Europe plays a leading role in green tech with booming exports. Society is polarised. On the one hand, there are high-performing export-driven businesses at the forefront of innovation in many fields (energy, biotechnology, construction, materials science, transport). These are oriented towards meeting global needs and they employ a highly educated segment of the population. On the other hand, the remaining large set of less dynamic, stagnated businesses focus on non-green internal markets, serving the majority of the European population facing deteriorating standards of living and suffering from the numerous damages caused by natural disasters. Due to a lack of resources and the lack of a skilled workforce, these companies in non-green sectors are trapped in vicious cycles and falling behind in integrating green solutions in their operations.

Scenario C: Feeling the pain: A workforce left behind in a non-green world
This scenario represents increasing environmental pressures from man-made climate change that have not been effectively addressed over the past decades. The EU is a follower, not a leader. It does not sit at the top table of global leadership on the development, deployment, and utilisation of green technologies. It follows the strategies, timescales, actions, and programmes set by others. The majority of green industry titans are located outside of Europe, e.g. in China, India, and the USA, and the European ability to set any form of industry standards is limited. EU strategic autonomy is low. The technological capacity, e.g. in the

digital realm, of the region fails to meet the level of the global forerunners. People in 2050 are dealing with rising temperatures, accelerated loss of biodiversity and nature, increased pollution, and more adverse weather events. A significant number of green jobs concern themselves with adaptation to system pressures and even systems breakdowns, i.e. limiting the negative impacts of environmental damages. This has impacted jobs because EU employers have little demand for green skills. The main industrial and innovation organisations are based outside Europe and are using remote working and technology to undertake many job roles and tasks. Over the past three decades, people have been investing in green skills believing that these will be in demand. However, the state of the EU green market means that many of these skills are now redundant or outdated. Consequently, there is an oversupply of green skilled labour from those already in the labour market and those seeking to enter it.

Scenario D: Green leapfrogging: Old, mismatched Europe surrounded by new green giants
In 2050, third countries and regions have leapfrogged leaving Europe behind. The world has seen geopolitical shifts, but also an improved environment. Young people leave the EU to work in countries with positive green agendas. Companies and individuals use non-EU green skills systems, and since the European skills ecosystem has been lagging, individuals find ways to acquire skills demanded by employers in informal ways. Lack of European leadership also results in the transfer of European companies to other regions, limiting the effective control of the European Community, an ethos that also becomes outdated as the global community adopts more cooperative approaches to enabling a just transition for all. Countries within the EU begin to align themselves with non-EU green leaders rather than promote unity from within. Skills systems are out of sync with global developments towards a just transition for all, and strange new demographic combinations arise to match old and new skills gaps. Since most green technology products are produced outside Europe, there is an increased focus on providing other goods and services (e.g. bespoke wine and cheese). Towards 2050, the EU is in 'catch-up mode' trying to restructure the economic and skills ecosystems towards modes more aligned within planetary boundaries and with the green, global development trends.

Each of the four depicted futures stimulated further discussion on multiple implications for current R&I policy, and collectively gave rise to the following conclusions:

There will be no green transition without a strong, vocational education and training (VET) skills base.

- Green skills training and development is crucial for developing a greener Europe, delivering a European Green Deal, and achieving a just global transition.
- Green skills should be developed for low, medium, and high-technology professions. VET and VET systems play very important roles in making green developments possible.
- It will be useful to address and improve short-term skills programming to enable fast responses to the impacts of climate change. For example, focusing on transferable skills that underpin a range of occupations and can move people quickly into new job roles.
- Similarly, sufficient levels of investment should be directed towards low-tech solutions that help make green improvements widespread.

Our shared understanding of what green means is reconfigured over time.

- What we consider 'green' today, may appear in a different light looking back from 2050. Research and Innovation (R&I) policy must include mechanisms for continuous reassessment of 'greenness' to avoid overinvesting in technologies and solutions no longer considered to constitute green improvements.
- Strategic foresight can be utilized as one mechanism for anticipating future shifts in society's understanding of greenness. This is important for R&D policy to avoid overinvestment in technologies and solutions that are no longer seen as green by the time they are market-ready.

The talent base for green skills must be expanded.

- Since demographic pressures with a decreasing population of labour-market age might make it difficult for Europe to meet a high demand for green jobs greater diversity and inclusivity are needed in the green job market. For example, gender balances should be addressed as 72% of green jobs today are held by males.

- Promoting inclusiveness should be a key focus in skills ecosystem policy planning. In addition, initiatives can be considered related to a more balanced gender share and in planning greater inclusiveness in universities and research organisations working with green technologies.

Green transition requires European and international cooperation in R&I policy.

- Much of the fate of the green transition will depend upon the developments in the Global South and emerging economies outside Europe. Greater international collaboration on green skills development could guide the transition in a greener and more just direction, while, at the same time, minimize the risk that Europe is left behind or outside international developments.

Green development paths are shaped by emerging technologies; emerging technologies should also be shaped by green skills.

- Finally, the trajectory and impact of new technologies such as AI are one of unknowns across all scenarios. However, it seems that the technological trajectory will affect some types of green work in the future. Attention should therefore be directed to monitoring how emerging technologies shift green job functions and how they change green skills demands - and towards implementing the reflecting changes in the skills training. At the same time, there is no guarantee that emerging technologies turn out environmentally sound. Integrating green skills and concepts of greenness in technological development and in orchestrating technological uptake would therefore be recommended.

There is no certainty that the long-term development of green skills and green jobs in Europe will be linear nor is there a guarantee that the supply of green labour market skills will match the green labour market skills demand. Instead, a successful match of supply and demand requires an active and continuous adaptation of the European green skills ecosystem. European R&I policy should underpin this continuous reconfiguration.

Although the future is uncertain, some initiatives are seen as 'no-regret' moves, i.e. they will be helpful in any of the plausible future scenarios. Such moves include a strong push for VET training, transferable skills, and short-term skills programming. This would strengthen the resilience of the European green skills base no matter the development path. A green labour market fit for everyone - i.e. using R&I investments to address not only high-tech, but also low and medium-tech professions, for instance in forest stewardship and maintenance and repair of devices; enhancing diversity, inclusiveness, and gender balances - is another core concern that would benefit Europe in any of the plausible, future scenarios. Finally, it is recommended to consider how initiatives can ensure that European R&I policy reflects the fact that our shared understanding of 'green' changes over time. This is the one thing that this brief can state with almost full certainty: An analysis of *green* skills and *green* jobs done in 2050 will feature a different understanding of *green* compared to a forward-looking analysis done from the vantage point of 2023. How can R&I policy help both anticipate such shifts and adapt to them?

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1 Introduction

Climate change and environmental degradation are an existential threat to the European Union and to the world. The European Green Deal aims to make Europe climate-neutral by 2050, boost the economy through green technology, create sustainable industry and transport, and cut pollution. The transition towards greener and more sustainable economies is a game changer in the EU labour market alongside digitalisation and automation. Skill[2] needs will change with impacts far beyond the key occupations driving them, affecting all economic sectors. Up- and reskilling of the workforce needs to be accelerated to meet the growing green skill[3] needs and also to prepare for matching the demand for new types of green jobs in the future.

Green jobs can broadly be defined[4] as (Dickinson et al, 2022[5]):

1) New and emerging green occupations;
2) Green and enhanced skills and knowledge occupations; and,
3) Green increased demand occupations.

There is a tradition of defining green jobs as by default good-quality jobs, i.e. with adequate wages, safe working conditions, reasonable career prospects, worker rights, etc[6]. Another perspective on 'good' jobs could lead to the conclusion that there can be 'good' jobs in 'bad' sectors (e.g. high GHG-emitting industries) and 'bad' jobs in 'good' sectors (e.g. producers of renewables).[7] In reality, many current jobs in green sectors, from waste processing to vegetable farming, are unlikely to meet the 'good-quality job' criteria, but their importance should not be overlooked. However, summarily, the EU's ambition for green jobs is a quest "*for good jobs in good sectors, i.e. jobs that entail satisfactory conditions from a static and dynamic perspective, in sectors that are economically, socially and environmentally sustainable*."[8]

The green transition will lead to new jobs being created and some jobs being replaced. The definition notwithstanding, the demand for **'green jobs'** has been and will be growing. Meeting the targets of the European Green Deal (EGD) translates into approximately 2.5 million additional jobs in the EU up to 2030.[9] The future of jobs is green, as one JRC publication puts it[10]. According to WEF, there is currently a shortage of 12 million green jobs across ten countries[11].

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[2] Learned and applied abilities that use one's knowledge effectively in execution or performance.

[3] Cedefop defines green skills and knowledge concepts as the knowledge, abilities, values and attitudes needed to live in, develop and support a society which reduces the impact of human activity on the environment (European Centre for the Development of Vocational Training, Cedefop, https://www.cedefop.europa.eu/files/9166_en.pdf).

[4] This is an expansive definition. The traditional 'purist' approach centers on jobs in industries with economic activities directly focused on producting environmental and climate change related goods and services, e.g. wind turbines and solar panels. See e.g. the discussion in Sofroniou, N. & Anderson, P. (2021). The green factor: Unpacking green job growth. International Labour Review, 160(1), 21-41.

[5] https://warwick.ac.uk/fac/soc/ier/researchthemesoverview/researchprojects/greenjobsandgreeneconomyyork/york_green_jobs_and_skills_report_final_report.pdf

[6] Sofroniou, N. & Anderson, P. (2021). The green factor: Unpacking green job growth. International Labour Review, 160(1), 21-41.

[7] Thus, caution needs to be made in labelling jobs green or not as it depends on both the organisational context and the performance in the job. For instance, if a green marketing position in the polluting company is green or just greenwashing depends on how serious the company and the green marketer are about green transition.

[8] ESIR Focus Paper (2023), https://op.europa.eu/en/publication-detail/-/publication/948cbd47-2147-11ee-94cb-01aa75ed71a1/language-en/format-PDF/source-289416748, p 10-11. This approach Is not selt-explanatory - one could also take the perspective that there can be 'good' jobs in 'bad' sectors (e.g. high GHG-emitting industries) and 'bad' jobs in 'good' sectors (e.g. producers of renewables).

[9] https://www.cedefop.europa.eu/files/4206_en.pdf

[10] https://publications.jrc.ec.europa.eu/repository/handle/JRC126047

[11] Australia, Brazil, China, Germany, India, Japan, South Africa, Spain, the UK and the USA, ref.
https://www.weforum.org/agenda/2023/01/social-green-jobs-sustainable-world-davos23/
https://www3.weforum.org/docs/WEF_Jobs_of_Tomorrow_2023.pdf

This has led to a concern about a sufficient supply of **green** skills. Demand for **future skills** is, for example, highlighted in the European Commissions' 2023 Strategic Foresight Report[12] as one of six key challenges for the EU's sustainability transition.

In 2022, the European Commission published a taxonomy (classification system) of skills for the green transition in European Skills, Competencies, Qualifications, and Occupations (ESCO). It includes **381 skills**, 185 knowledge concepts, and 5 transversal skills considered most relevant for a greener labour market. Examples of 'green skills' include training staff on recycling programmes or how to design and conduct energy audits and measure the sustainability of tourism activities, for instance. This broad classification serves to indicate that green skills are applied in a very wide range of jobs across all sectors of the economy. They also highlight how ESCO conceptualizes 'skills' as covering both highly complex technological, scientific, and engineering competencies, vocational and craft competencies and social and communicative skills. A similar broad understanding is applied as the starting point for this study.

The changes already underway might entail the need for Europe to *promote and support green employment*, *address the skilling and reskilling of workers*, and *anticipate changes in workplaces of the future*. However, most work on green skills and jobs has been around short-term implications of technological, scientific, and social developments/changes on skill requirements, and the number and distribution of green jobs[13]. While general sustainability education and green competencies are increasingly addressed, a possible shortage of labour supply is rarely tackled. A potential long-term situation in which skills acquired for the green transition are transformed into a post-transition oversupply of green skills is also rarely considered, although this too would have consequences for optimal policies and optimal resource allocation.

In this brief, we develop four alternative scenarios on the state of green skills and jobs and their demand and offer in the European Union by 2050, including considerations of global leadership in green technologies. The role of research and innovation (R&I), technological change (especially AI), infrastructure needs, and institutional change are also considered. Furthermore, the scenarios serve to develop implications for research and innovation (R&I) policy in Europe.

[12] https://commission.europa.eu/system/files/2023-07/SFR-23_en.pdf

[13] https://climate-pact.europa.eu/about/priority-topics/green-skills_en
https://publications.jrc.ec.europa.eu/repository/handle/JRC127822
https://climate-pact.europa.eu/about/priority-topics/green-skills_en
https://publications.jrc.ec.europa.eu/repository/handle/JRC126047

2 Identifying four scenarios on green skills and jobs in Europe in 2050: Methodology and key dimensions

This policy brief presents the findings from foresight[14] work on alternative scenarios, narratives of the future (written in the present tense, as if we were already in the future). These scenarios are not predictions. Rather, they depict possible futures.[15] First, we identified key factors of change (see Annex 2), which helped us define four dichotomic dimensions to provide a structure for the scenario work.

We focused on the dimensions that reflect key uncertainties and bring out significantly different alternative futures, while also reflecting our context of European R&I foresight. Thus, we selected the dimensions that help differentiating the scenarios by capturing the future state of the natural environment, green technology leadership, and the demand for and offer of a green workforce. The leadership in green technology and the state of the environment mirror the EU aspirations projected in the Green Deal. Green technology leadership relates to the number and size of the green business in Europe and thus also the number of green jobs needed. Furthermore, aligned with the scope of the exercise and in general attainment of policy objectives, we also consider the demand and offer of green skills and jobs. This helps us relate the work with implications on research and innovation (R&I) policy.

Key dimensions and their two extremes for structuring the scenarios
Dimension 1. Environment - *Environment (negative extreme)* Environmental pressures are exacerbated. People in 2050 are dealing with rising temperatures, accelerated loss of biodiversity and nature, increased pollution, and more adverse weather events. A significant amount of green jobs concern themselves with adaptation to system pressures and even systems breakdowns, i.e. limiting the negative impacts of environmental damages. *+ Environment (positive extreme)* By 2050, a sustainable and just transition is near completion. Fossil fuels are phased out, the EU has achieved its Net Zero targets, and global GHG emissions are in line with, or near, the Paris Agreement. Biodiversity loss has been halted, and nature restoration is in full bloom. The demand for green occupations tied to the green transition is reduced; however, new green occupations may have emerged.
Dimension 2: EU leadership in green technologies - *EU leadership (negative extreme)* The majority of green industry titans are located outside of Europe, e.g. in China, India, and the USA, and the European ability to set any form of industry standards is limited. EU strategic autonomy is low. The technological capacity, e.g. in the digital realm, of the region fails to meet the level of the global forerunners. *+ EU leadership (positive extreme)* EU is considered a world leader in green technologies, and a significant share of global R&D as well as production jobs related to green products are located in Europe.
Dimension 3: Demand for green workforce - *Low demand for green skills (negative extreme)* By 2050, the labour market demand for green skills in Europe is, comparatively, low.

[14] Foresight uses several methods that complement each other and help rendering outcomes thought-provoking, even presenting surprising ideas about future developments that are amenable for further elaboration by policymakers and other stakeholders. While the objective is to have a balanced representation of diverse stakeholder views, in practice the process depends on the context in time and the subsequent readiness of stakeholders to engage. Efforts were made to cover the wider possible range of diverse perspectives, although the results chiefly rely on the contributions of those actively involved in the process. Using a structured dialogue, the process offered opportunities for mutual learning among participants to explore together possible futures and reflect on related policy implications.

[15] Exploring multiple scenarios helps expand one's own span of observation further towards the future, to possible threats and opportunities that might not be in the immediate attention span or might be excluded for being unlikely.

+ High demand for green skills (positive extreme)
By 2050, the demand for green skills in the labour market has expanded rapidly. Most jobs require green skills. European and national policies ensure that the skills ecosystems manage to deliver green skills.

Dimension 4: Offer of green workforce
- Low supply of green workers (negative extreme)
There is only limited availability of workers in the European job market in 2050, who are able to fill green jobs.

+ High supply of green workers (positive extreme
By 2050, a very significant number of employees around Europe possess green skills and have the competencies to fill green jobs.

While the dimensions are used to identify dominant features, alternative practices are also considered in the scenarios though always in relation to the dominant features. The scenarios are defined by selecting one of the two extremes of each dimension. In Figure 1, the dimensions are presented in pairs in vertical and horizontal access. The dimensions of the economic model and the production and environment provide the large axes in which we inserted the second axes of governance and trust society. Thus, this creates a structure of 16 alternative futures for scenario development. Out of the 16 alternative futures, four scenarios located within the scenario framework were selected ensuring for further analysis making sure of maximum diversity among the scenarios and building on the consultations of the expert team and the scenario workshop participants. These were the scenarios considered by participants as the most interesting to work with. In particular, each of the four scenarios chosen for further exploration involves tensions, especially a mismatch between demand and supply for green skills with major policy implications. Hence, we left out a series of alternative futures with less labour market tension and, for that reason, fewer policy issues to solve[16]. the selected scenarios are all internally coherent and represent plausible future outcomes, but they differ from each other on key scenario dimensions.

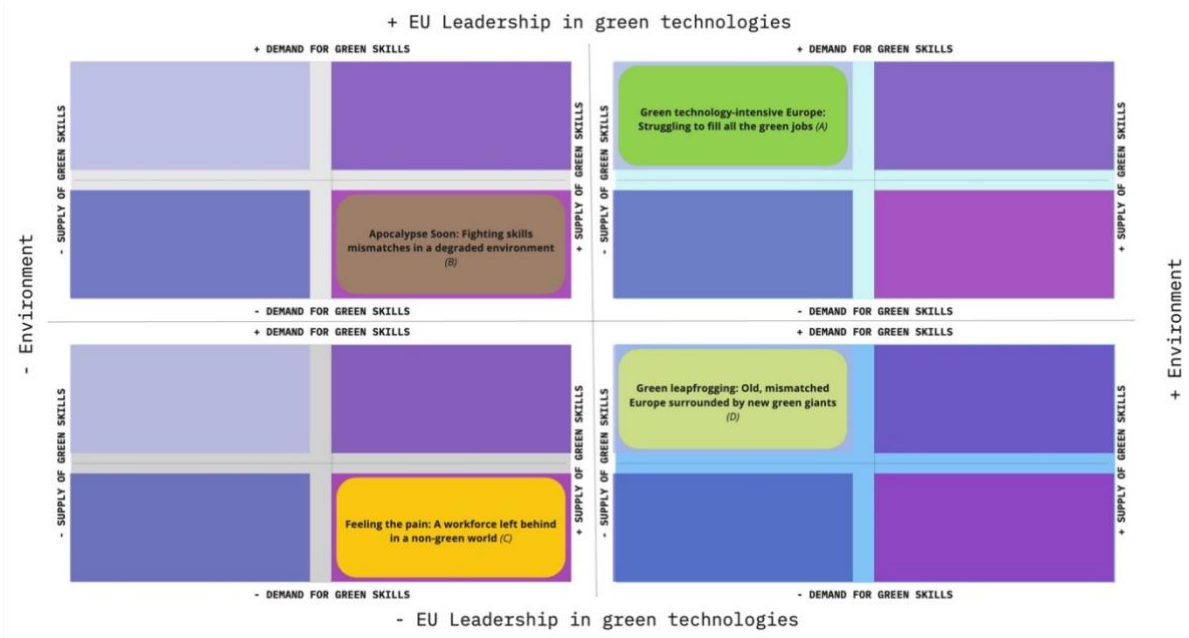

Figure 1. A structure of 16 alternative futures and the positioning of the four scenarios.

Source: The authors.

[16] From a labour market perspective, both the top right (high supply, high demand) and the bottom left (low supply low demand) involve a lot less tensions than situations with high supply and low demand (resulting in unemployment) or low supply and high demand (resulting in bottlenecks).

The four scenarios reflect distinct states in 2050 of the combinations of the development of the environment and of Europe's role in the world. Within each scenario both positive and negative elements can be found, although some futures are clearly more attractive than others. The main distinguishing features of the four scenarios are summarized in Table 1 below.

Summarizing the scenarios

Table 1. Scenario summary table

SCENARIO TITLE	SCENARIO A *GREEN, TECHNOLOGY INTENSIVE EUROPE*	SCENARIO B *APOCALYPSE SOON*	SCENARIO C *FEELING THE PAIN*	SCENARIO D *GREEN LEAPFROGGING*
CORE DRIVER	Joint green transition efforts across society including social and technological green innovations.	Polarization of the European economy with export-oriented green technology companies vs. domestic-oriented outdated unsustainable companies.	The EU was demoted from the vanguard of technological progress to the guard's van.	A Global South Green Deal leads to significantly positive environmental change.
TYPE OF GREEN SKILLS	Continuous high demand for green skilled workers (e.g., deep ecology, circular economy, climate prediction, etc). Both high-tech and low-tech skills.	Skills development is in the hands of - successful - green technology export-oriented companies, while most of the companies suffer from green skills shortages	Low demand, mainly medium/low-tech green solutions (e.g. building insulation).	The EU green skills system lags behind the rest of the world, failing to develop in sync with either EU or wider demands for green skills.
STATE OF GREEN JOBS	Many green jobs, but demand outpaces supply (also due to European demographics).	Green technology companies recruit without difficulty and offer good salaries - unlike other sectors of the economy.	EU green jobs deploy and maintain others' technological solutions. Leading-edge green jobs are outside of Europe.	New green jobs are more collaborative, and oriented towards sustainable value creation.
EU AGENCY	EU leads, e.g. through promoting multidisciplinary research and comprehensive solutions.	EU promotes well-established green technology companies but takes little independent action.	EU, Member States, and regional governments are fractured and fragmented on the green agenda.	Struggling to keep up with the global leapfrogging. Failure of transforming earlier assumptions, job creation models, and training systems.
R&I POLICY FOCUS	Broad European research collaboration, access-for-all lifelong learning infrastructure.	Support for green technology companies.	Managing what's left. (R&I capacity in the EU is largely owned and managed by overseas countries/businesses.)	EU focus is internal; lack of coherence in green R&I policymaking.
CORE METAPHOR	Europe is illuminating the path to a brighter, greener future, but an ageing population casts a shadow over the abundance of green opportunities.	Polarisation: Prosperous, export-oriented green technology companies vs. domestic-oriented companies; highly trained workers vs. precarious workers with a low professional level; skilled work vs. work bordering on the informal.	The situation in the disaster movie before the heroes arrive. Bad and damaging effects of climate change, but no EU leadership techno-logical or otherwise, and the labour market suffers as a result.	Youthful populations in the global South not only demanded but needed a better future - and they succeeded in creating it. The EU as a taker.

3 Green, technology-intensive Europe: Struggling to fill all the green jobs (Scenario A)

Key dimensions:
EU leadership in green technologies.
Improved natural environment
High demand for green skills
Low offer of green workforce.

Figure 2. Green, technology-intensive Europe.

Source: AI-generated with Dall-E

In brief:
The European Union has advanced in a green transition across society and has gained global leadership in green technologies, resulting from aligned efforts. The EU is exporting the accumulated green knowhow and technologies and has become an engine for leading the world on a transition path towards a greener planet. Although past emissions continue to heat the globe, the world has avoided reaching major tipping points and the climate is gradually recovering. Europe is the global leader in the development and deployment of climate change mitigation technologies which, among others, reduce greenhouse gas emissions, generate renewable energy, and provide sustainable food production. Europe shows the way in the production of clean energy and its distribution to homes, businesses, and industries. Energy consumption is supplied by renewable energy sources (solar, wind, hydroelectric, and geothermal power) and nuclear energy. Europe is also excelling in climate change adaptation technologies that protect citizens against frequent, extreme, and severe weather conditions, such as heatwaves, floods, hurricanes, and forest fires. However, Europe has experienced a demographic shift. The population has aged and the total population has shrunken. Consequently, there is a low offer of labour, and specifically there is a low offer of green skilled workers. Job offers in renewable energy technology, green construction and sustainable urban planning are hard to fill.

How did we get here?
Over the past years, the European Union has been heavily investing in technologies that help curb climate change and avoid tipping points, which could have led to irreversible and catastrophic consequences if unattended. In the last decades, Europe has succeeded in developing various technological advancements that allow societies to successfully mitigate the still present negative effects of past climate change. As a result, climate change has been slowed down and Europe is on a successful trajectory towards a greener environment. During the past decades, education and training programs have focused on environmental skills, and there is a shift towards more sustainable consumption patterns. Europe as a society has been adapting to the consequences of climate change. Since, 2020, governments have implemented ambitious environmental policies, leading to a surge in green jobs. Renewable energy, energy efficiency, sustainable agriculture, and green transportation sectors thrive and there is a continuous high demand for green skilled workers.

Key drivers:

Society and environment
Europeans have changed their lifestyles and are aware of their ecological footprint over the past decades. The mantra has become "*reduce, reuse, repair, and recycle".* European policy and business have jointly managed to offer European citizens affordable options to make thoughtful choices when buying products. Europeans embrace mindful consumption, use fewer products, consume fewer resources and generate less waste. European regulations help firms "design for eternal life" instead of "design for quick rebuy".

Repairing and reusing products extends their lifespan, reducing the need to purchase new items, and reducing the environmental impact associated with manufacturing and disposing of products.

Sustainable and healthier lifestyles contribute to improved public health. Human health - physical and mental - has come to be seen as a key component of sustainability and, by extension, as 'green'. As negative effects of climate change still occur, the health sector is equipped to address the health impacts of extreme weather events and more frequent occurrences of pandemics. Health professionals implement preventive measures and provide care to those affected. To be aware of upcoming climate-related issues, health professionals collaborate with environmental scientists and climate experts to track disease patterns and assess the effectiveness of mitigation measures.

Demographics

Europe has experienced a demographic shift; it has shrunken and aged. Some of the older workforce in traditional industries are seeking retraining and a transition to green careers, but too often early retirement is felt more attractive. This has reversed decades-long trends of a rising retirement age. The green technology sector has been attracting a young workforce with multiple career options across industries with innovation and sustainability.

European cities have gained traction with sustainable and healthy urban planning that has brought nature into the cities and combined previously separated recreational, residential, office, and commercial areas in an attractive way. Cheap efficient ways of transportation have made it possible to overcome traffic congestion. Cities and communities have invested in green infrastructure, including green roofs, urban gardens, and sustainable building practices, to mitigate the urban heat island effect and enhance urban resilience. Part of this trend of greening the cities is also green jobs, which often concentrate in urban areas where research, innovation, and sustainability initiatives are centred, urbanization has further increased.

Agriculture

European farming has moved toward a diversified landscape of farming activities. The need for farmland has been cut back by virtue of the move towards plant-based diets and new technological developments generating higher yields, for instance, the deployment of intensified insect-based protein production requiring limited space. The remaining farmland serves multiple goals, namely energy production on top of food production, by having food production under solar panels and animals grazing under wind turbines.

Three trends are prevailing in 2050. First, local and regional food has become the mainstream with smaller farms located close to consumption both in urban and rural areas. Second, EU farmers are frequently organised in living labs, and have for instance developed a wide variety of plant-based alternatives to dairy and meat products. Third, in contrast to the diverse small unit size mainstream activities, several large agricultural operations further away from urban centres have emerged that can hardly be called “farms” anymore. Here, farming has become a highly specialized profession requiring acvanced technological skills, as well as skills enabling producers to grasp strict regulatory frameworks and the complexities of global consumer preferences.

Less globalisation, going local

Europe is actively working towards attaining self-reliance in key areas, including vital goods, food, medicines, materials, and energy. The trend of “producing for local consumption” ties in with this overall trend of Europe becoming self-sustainable. Automated urban mining solutions allowed to turn landfills into valuable raw materials for industry and agriculture. As Europe is now running out of landfills, the promotors of these technologies have turned their attention to third countries. Other industry sectors are also offering their know-how in the global markets providing solutions to close loops of material flows, for instance, every piece of vehicles of all sizes and electric appliances of all types are dismantled, refurbished, and reused. Green technologies are a strategic resource that determines the geopolitical position of Europe. Core technologies will be protected as they could be prone to abuse if in the hands of politically volatile economies.

Technology

Digital technologies, including AI and machine learning algorithms, play a crucial role in monitoring and optimizing renewable energy systems, managing smart grids, developing climate modelling and prediction tools, and enhancing biotechnology solutions and the efficiency of sustainable agriculture and transportation. As a result, there is a growing need for professionals with expertise in digital technologies, data analysis, and AI in these green industries. High-skill green jobs require digital skills far exceeding what was the norm back in the 2020s. Upskilling and retraining programs become crucial to address the digital skills gap. Traditional office-based roles decline, but digital and tech-related jobs flourish.

Education and training
The education systems were slow to fully integrate green skills in their curricula, but pressure from market actors accelerated the shit. Today, sustainability lessons are included by default in every course at every educational level. VET progras have shifted the focus from the installation of renewable energy systems to the reparation and maintenance of a wide set of electric appliances. Environmental skills, not only specific technical skills (e.g. sustainable civil and electric engineering and construction) are taught, but also cross-cutting civic and community resilience skills for crisis preparedness and self-sufficiency both in terms of physical security and first-aid and food production, as well as mental health-related skills, including addressing distress tolerance and mental recovery. Resilience and adaptability are highlighted as key green skills boosting all individuals.

In higher education, sustainability is also integrated horizontally and degrees in AI- and biotech-driven environmental design for biomimicry and circular business practices are in high demand. Also, foodtech studies are favoured by many students spurred by success stories of start-ups that have moved society to being increasingly plant-based and using proteins-based diets. By building bridges between the above skill needs and diverse application areas, living labs serve as educational platforms, providing opportunities for students, researchers, and professionals to gain practical experience in research, innovation, and entrepreneurship. Continuous learning, reskilling, and upskilling have become essential to keep up with changing job requirements.

Labour market
The high demand for green skills and its limited supply in 2050 is leading to increased competition in the labour market. As the competition leads to greater job rotation, individual must continuously update their skills (upskilling and reskilling) to fit new positions. Lifelong learning programs are important for employers to remain competitive. The high demand for green skills attracts individuals, especially young people, to green careers. A growing number of students and professionals pursue education and training in green skills, which has led to a more educated and technically proficient labour force. Furthermore, the green economy fosters entrepreneurial endeavours, with more individuals starting their green technology businesses or eco-friendly ventures, which has led to an increase in the number of small and medium-sized enterprises (SMEs) focused on sustainability. Additionally, European regions with a strong green economy and abundant green job opportunities have experienced immigration as people from other regions (also from outside the EU) sought better employment prospects. Conversely, areas with fewer green job opportunities have experienced emigration. Given the global nature of environmental challenges, an increased collaboration occurs among European and non-European countries and regions concerning research, technology transfer, and environmental protection efforts. This has led to more diverse and international workforces in green sectors.

Key take-aways for current policymakers derived from Scenario A
European policymakers are advised to prioritize strategies to align green skills supply to regulatory advances and to identify and address the shortages of green-skilled workers and the need for green technologies.

This can be done by promoting education and training programs to align with regulatory changes and meet the high demand in the renewable energy, energy efficiency, sustainable agriculture, and green transportation sectors and by stimulating research and research collaborations that address green topics. In this way, the EU can fully capitalize on Europe's technological advancements in mitigating climate change and sustain its leadership in green technologies.

4 Apocalypse Soon: Fighting skills mismatches in a degraded environment (Scenario B)

Key dimensions:
EU leadership in green technologies.
Very degraded environment
Low demand of green skills
High supply of green skills but skills mismatch: green workforce available, but not appropriate for the needs of the labour market (even if the needs of green technologies are covered).

Figure 3. Apocalypse Soon.

Source: AI-generated with Dall-E.

In brief:
After failed climate policy efforts, a sharp deterioration of the climate and the multiplication of extreme natural-related events, the environment is in a critical state in Europe and globally. Europe plays a leading role in green tech with booming exports. However, this is with a subset of the private sector in the driver's seat, while public oversight and agency is limited. Society is polarised. On the one hand, there are high-performing export-driven businesses at the forefront of innovation in many fields (energy, biotechnology, construction, materials science, transport). These are oriented towards meeting global needs and employ a highly educated segment of the population. On the other hand, the remaining large set of less dynamic, stagnated businesses focus on non-green internal markets, serving a majority of the population facing deteriorating standards of living and suffering from the numerous damages caused by natural disasters. Due to a lack of resources and the lack of a skilled workforce, these companies in non-green sectors are trapped in vicious cycles and falling behind in integrating green solutions in their operations.

How did we get here?
Throughout the 2020s, the number of natural disasters in Europe increased. The European Union's response has been primarily technological: development of renewable energies, adaptation of housing, investment in biotechnologies, etc. Thanks to significant financial incentives and rapid advances in new technologies (artificial intelligence, automated production, etc.), high-level green businesses have rapidly developed. At the same time, and throughout the following decades, the European Union accumulated delays in reducing greenhouse gas emissions in order not to alienate businesses or the general public by forcing them to radically change their production and consumption patterns. The number and intensity of extreme natural phenomena have increased dramatically over time, resulting in global impoverishment that is unevenly distributed. The strong tendencies towards polarisation (political, social, economic, sociological, etc.) in society that existed at the start of the period have worsened throughout the 2030s and 2040s. The European Union of 2050 is dual: a green Europe for the happy few, and a environmentally and economically degraded Europe for the remaining majority of the population.

Key drivers:
In 2050, companies in the European Union's green technology sector once again broke their export turnover records. The construction of zero-energy buildings that can withstand extreme weather conditions, the remediation of polluted soils, the adaptation of plant species to drought and soil salinisation, the recycling of plastics, and alternative energies - there are few green fields in which the expertise of European companies is not recognised on a global scale. However, much of the European green tech products, while 'designed in Europe', are largely manufactured in the Far East. European companies import almost-ready product parts, assemble them for export them to third countries, and thus generate only a few jobs in

Europe. Even if some work has been carried out to protect the coastline and large-scale green hydrogen production facilities are in operation, companies in green sectors have invested little in Europe. Similarly, for example, the work carried out to adapt older buildings to the climate falls far short of what is needed.

A deteriorating economic situation
In this scenario, Europe's economic circumstances are difficult. Increasingly severe natural phenomena has made it impossible to insure against the risk of natural disasters, at least without market rates commensurate with the high risks. Lacking insurance most disaster victims make do with the limited compensation paid out by government's emergency funds.

European agriculture suffer from decreasing crop tields caused by more frequent and increasingly long-lasting droughts. New seed varities are expensive, and even they are not always resilient in a very unstable climate. Use of modern, modified seeds is also highgly controversial in the turbulent social context. Tourism has been affected by climate change. Once sought-after seaside resorts struggle with rising temperatures and water supply problems (neighbouring areas affected by desertification). The emergence of new leisure centres where customers can enjoy domesticated nature under a bubble has not been enough to offset the general decline in tourism.

Political choices for the benefit of exporting companies
Against this backdrop, the GDP of EU Member States is stagnating or even declining. State budgets are drained by the level of spending needed for maintaining and repairing infrastructures, damaged by the consequences of climate change, and the emergency funding expenditures. To compensate for limited state capacity, private sector investments are incentivised e.g. with tax credits for developing the most advanced green technologies. Universities are also strongly encouraged to forge partnerships with businesses to supplement increasingly inadequate state funding. Green skills are privatised, but know-how and products of European green technology companies are recognised and sold throughout the world.

Polarisation of businesses, employment, training, and personal incomes
Most households see their standard of living stagnate or decline in a context of stagflation: growth is zero or even negative, and inflation is fuelled by rising commodity prices. Middle income groups are being impoverished and society is becoming increasingly polarised.

The economy is also polarised. On the one hand, there are high added-value, highly profitable activities, such as the green technology companies mentioned above. On the other hand, there are activities geared towards the now-poorer domestic market, which are suffering from the sluggish economic climate and in which the green component remains marginal. The automation of activities, in industry and services, has contributed to labour market polarisation by eliminating many low-skilled routine tasks. The reorganisation of production has also led to increased subcontracting within large, technologically advanced companies to companies specialising in the execution of low-tech, contract work, where wages are adjusted downwards because of increased competition. The gap between these two types of companies and jobs has become so wide that some characterise it as economic segregation at work, which affects social cohesion.

A political power and a society at the end of their tether
Society is marred by economic polarisation between the well-off and those who have become poorer. This fuels an advance of conspiracies, anti-science opinions, and esoteric beliefs. Questioning the anthropogenic nature of climate change is widespread. Some even claim that the various natural disasters that have occurred are the result of manipulations attributed to malign forces, identified or not. While there is global widespread societal pessimism related to green technology companies, the corporations seem to march on unaffected. This is not unlike the global dominance of a small group of elite digital and social media companies succeeding amidst a so-called tech backlash back in the 2015-2025 period. Social order is maintained by governments that have largely adopted illiberal policies. Society is fractured: Social cohesion has been destroyed.

Green skills and green jobs:

At the top end of the qualification and salary scale, jobs are massively concentrated in high-tech companies: These work functions are essentially conceptual, with the first practical applications in the form of pilot installations on a semi-industrial scale in the laboratory or in real-life situations. Real-life tests have been reduced thanks to major advances in modelling (decreasing also routine-level jobs within the green industry). Carrying out this work requires workers, with multidisciplinary skills, who have received good initial training, which companies give them the means to maintain as part of ongoing training to which considerable financial and technical resources are devoted. Green tech companies employ generalists and specialists who can design sophisticated products, while the pilot-plants are run with the help of high-level technicians.

Some of the main green job-creating sectors in 2050 are:

- Energy (demand for energy remains remarkably high, notably because of the increased usage of ICT and AI);
- Design of buildings and infrastructures that combine good resistance with a low environmental footprint (energy, treatment and recycling of fluids, etc.) and comply with a standardisation system that reduces the costs associated with environmental constraints;
- The development and production of new materials, particularly composite materials, which combine lower consumption of raw materials, the supply of which is under pressure, with an emphasis on the use of renewable resources; these new composite materials also have the distinctive feature of being easy to recycle at the end of their life cycle, since specific techniques have been developed that enable their various components to be separated efficiently;
- The transport industry, with modes of transport that use alternative energies (hydrogen, electric batteries), making it possible to do away with the most delicate infrastructures that are most likely to be destroyed in the event of extreme climatic phenomena;
- Biotechnologies whose field of activity is very large: creation of seeds and plants adapted to new climatic conditions, selected based on their capacity to resist in particular the droughts and to the salinisation of the agricultural land, putting in work GMO and new genomic techniques; development of sanitary products de biocontrol to facilitate the mechanisms of natural defence plants and beneficial interactions between living beings environment.

Some of these sectors are addressing the domestic European market, where they are benefiting from the government emergency funds aimed at post-disaster rebuilding. Unfortunately, this helps to crowd out other sectors of the European economy. This is felt by those in low-skilled, low-paid jobs in companies serving other parts of the stagnating EU domestic market.

Companies survive by continuously adjusting their workforce to the contracts they obtain. Self-employment has developed strongly to the detriment of salaried employment and short-term fixed-term contracts have become even more common. This large part of the workforce is often poorly trained. Since financial resources of households and available public aid are limited, it is often difficult for the most disadvantaged groups to study. Initial vocational training is also often of short duration, as there is a structural problem with procuring adequate public funding. Employers prefer to recruit people who have completed specialised training that is directly and immediately usable in the workplace. Neither the domestically-focused companies nor the labour force have the means that would allow them to think long-term.

These types of jobs at the lower end of the social scale are rarely seen in green sectors. Here, the aim instead is to adapt production as far as possible to the climatic constraints of the time. For example:

- In the building industry, new construction and renovation projects are incorporating techniques that reduce energy consumption wherever possible, with cost as a limiting factor; installation and maintenance of geothermal systems,
- In the construction sector, a move towards the re-use of materials and household equipment that have already been used, or the use of alternative, more environmentally-friendly materials (cork or wood fibre panels, hemp bricks...),

- Production of consumer goods witnesses a greening by default through the simplification of models and their repairability,
- In all types of activity, the acquisition of knowledge enables mastery of technologies linked to new forms of energy supply (hydrogen or biomethane for example).

In terms of green skills, this implies basic knowledge: in the building industry, insulation techniques, or the maintenance of energy-saving heating systems; in industry, these greening jobs are more specifically in maintenance (electricity, mechanics). The workforce is polarised between those who have acquired these basic skills and those who haven't.

However, there are also greening activities happening outside the primary labour market. These are activities such as recovery, repair, reuse, and recycling that are difficult to automate; for example:
- the recovery of various wastes, the recycling of raw materials (metals, for example),
- the repair of cars or small items of equipment to prolong the life of these products,

These are craft-type activities, often carried out under unsatisfactory working conditions. There is practically no specialized training for these professions: Apprenticeship is done on the job, sometimes with minimal organization provided by local authorities or associations. This whole context has led to the development of a parallel economy (undeclared work) that has green components and which creates unfair competition for these recycling and repair businesses.

Since small businesses often compete with these low-paid undeclared work activities, it is difficult for new or small businesses to grow. Large companies with government contracts and access to world markets within their niches are, so far, insulated from this problem.

The period also sees the development of multiple part-time activities. These include small-scale gardening and animal husbandry to supplement household food supplies: individual or collective vegetable gardens, sometimes organised in conjunction with local authorities. These green activities scaled up rapidly and new techniques are being developed and adapted to the specific characteristics of small-scale farming:
- raising awareness of climatic hazards (sunshine, temperatures, extreme events),
- the knowledge of intercrop plant cover (natural nitrogen supply) and crop rotation,
- the knowledge of plant protection products and inputs.

Key take-away for current policymakers derived from Scenario B
In this scenario public authorities lost control of the situation because they wanted to protect the living conditions and activities of companies and individuals, without providing sufficient responses to climate change and other environmental degradation. In a fragmented society, all stakeholders were forced to adapt in the short term to the consequences of unpredictable natural phenomena, with no serious prospect of regaining control. A skill divide reinforces a social divide leading to a vicious circle of polarisation.

If there is a societal problem connected to short-term thinking created by rapid reactions to more and more 'surprise' adverse weather and environment-related events, how can this risk be alleviated by long-term thinking on R&I?

5 Feeling the pain: A workforce left behind in a non-green world (Scenario C)

Key dimensions:

Environmental pressures are exacerbated.

EU lags behind in green technologies.

Low demand for the green workforce and green skills.

High offer of green workforce, (supply) of green skills.

Figure 4. Feeling the pain.

Source: AI-generated with Dall-E.

In brief:

This scenario represents increasing environmental pressures from man-made climate change that have not been effectively addressed over the past decades. The EU is a follower, not a leader. The region or its companies does not sit at the top table of global leadership on the development, deployment, and utilisation of green technologies. It follows the strategies, timescales, actions, and programmes set by others. The majority of green industry titans are located outside of Europe, e.g. in China, India, and the USA, and the European ability to set any form of industry standards is limited. It is a globalised world, and the EU depends heavily on imports from other regions. The technological capacity, e.g. in the digital realm, of the region fails to meet the level of the global forerunners. People in 2050 are dealing with rising temperatures, accelerated loss of biodiversity and nature, increased pollution, and more adverse weather events. A significant amount of green jobs concern adaptation to system pressures and even systems breakdowns, i.e. limiting the negative impacts of environmental damages. This has impacted the demand of green jobs in the EU limited to most polluting heavy industries. The main industrial and innovation organisations are based outside Europe and are using remote working and technology to undertake many job roles and tasks. Over the past three decades, people have been investing in green skills believing that these will be in demand. However, the state of the EU green market means that many of these skills are now redundant or outdated.

How did we get here?

Although there was plenty of evidence of global warming, there was insufficient action. Excuses were always available not to devote sufficient financial and political resources to addressing man-made climate change: other countries aren't doing enough, wars in Ukraine and the Middle East, domestic economic conditions, the need to address other priorities, and the need to appease established interests. Fossil fuel industries were very effective at protecting themselves and propagating a false narrative which derailed many of the efforts to transfer resources to green solutions through polluter fines and fossil fuel taxes. There was little agreement on action as populist actors were able to sow division at regional, national and EU-levels so that political consensus to tackle climate change could not be achieved. As a result, technical and organisational expertise relocated to those countries that were increasingly leading the green transition and investing in green solutions. These places had the funding, skills, infrastructure, direction, commitment and heft that EU-climate change organisations required to innovate and prosper. The green labour market of the EU began to evaporate as jobs and skills demand relocated elsewhere. This Green vocational education and training (VET) provision in the EU were depleted as there has been less and less demand.

Key drivers:

Environment
The environmental risks and hazards of man-made climate change identified in IPPC (2018)[17] have come to happen on the land, in the sea, and in the air. The increase in the number, size, frequency, and location of impacts makes response planning and mitigation less effective leading to increased use and wastage of resources.

Demographic, lifestyle, and value drivers
The deteriorating natural environment leads to a reduction in life expectancy as rising health problems increase death rates. There is also a reduction in birth rates as people's expectations for the future of the planet and their current economic situation worsen.

There is increased demand for natural resources – land, water, and food – and this escalates polarisation in society as competition for scarcer resources intensifies. Rising inequalities and people's dissatisfaction with their standard and quality of life lead to greater and more intensive civil action and disobedience. This leads to greater demands for security and protection (public and private) and the rise of individual and community responses, such as gated communities which further divides society.

Economic drivers
There is little or no economic growth as the environment poses extra costs and problems to industry. Some sectors are expanding, such as health and social care, as the conditions and needs of vulnerable and older people increase. Certain traditional carbon-emitting industries, such as fossil fuel mining, drilling, and energy generation, have continued as environmental responses have been limited or faltered. Sectors such as agriculture and fishing face extreme challenges due to environmental impact on land, plant productivity, and sea life. Tourism has declined as heat waves make certain destinations too hot, and winter sports centres no longer have snow and ice. Attempts to reduce travel through taxation (e.g. frequent flyer levies) also make foreign travel more expensive. Petrol duties rise making land and sea travel costly.

Much of the green manufacturing, technologies, and innovation are based overseas. Green infrastructure, such as power generation and transport, is imported leading to increased employment, but this is lower-skilled work as professional and technical workers come from overseas companies. The digital economy thrives due to environmental challenges. More and more people work from home, as communications technology and the use of Augmented and Virtual Reality improves. Similarly, more socialising and recreation takes place in the virtual world.

Governance
The failure to address man-made climate change and its effects on the environment has fractured and fragmented governance at a variety of levels. Overall, across the EU and due to past failures, there is little agreement on how to address the increased environmental impacts at the political, economic, and social levels. At a global level, the ineffectiveness of past Conference of the Parties (COP) summits (due to them being usurped by pro-fossil fuel interests) has meant that there is now no world-wide leadership on climate change.

Governments at the EU, member state, regional, and local levels are split on what solutions (if any) to develop, and how to implement them. This lack of governance means that consistent approaches across the EU cannot be developed. There is no agreement on what green legislation, standards and regulation are to be implemented.

Technologies and social innovation

[17] IPCC (2018). Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty. Cambridge University Press, Cambridge, UK and New York, NY, USA, 616 pp. https://doi.org/ 10.1017/9781009157940.

The failure of green technologies to cope with the speed and severity of climate change led to disillusionment. Disruption to supply chains has triggered a growth in 3D printing and distributed manufacturing. New materials have supported these trends so products can more easily be printed locally and reliably. Fossil fuel companies continue with their investments in carbon capture, storage, and use. It is still not very effective, but the monetary might of these companies means that they still get political and financial support for their investments.

Local communities develop communal, green projects based on social innovation and low-tech solutions. For example, an increase in the reduce, repair, reuse, and recycle attitude leads to a growth in local repair shops and sharing e.g. toy and tool 'libraries', renting clothes, and buying second-hand goods.

Green skills and green jobs:
There are four types jobs related to green jobs: new and emerging[18]; enhanced skills and knowledge[19]; increased demand[20]; and non-green[21]. Due to governance and economic failures across the EU, green new and emerging occupations, which are related to developing green technologies, are now based mostly overseas. These are primarily highly skilled and qualified research, professional, and technical occupations. Whilst some of these jobs can be accessed remotely, organisations prefer their staff to be located close by and there is a 'brain drain' of highly qualified EU workers overseas. As non-EU countries and organisations are leading the development of green technologies, skills development is also increasingly being led by non-EU institutions. The most respected universities delivering green scientific, research, and technical training and qualifications are now based overseas which also leads to the relocation of many of the EU's higher education tutors and technicians. What higher education learning and development EU universities now deliver is mostly through collaboration with non-EU institutions or in overseas countries for their domestic markets.

With the fragmented governance, European political systems struggle to set and maintain local environmental regulations. Regulations and standards are therefore often copied from the world market, from legislative initiatives elsewhere, or based on the suggestions and lobbying efforts of non-European private corporations.

Green enhanced skills and knowledge occupations depend on the development of green technologies and responses. However, because green technologies are now mostly imported, skilled staff usually come from the host country. The green enhanced skills and knowledge occupations are now mostly lower-skilled installation and maintenance jobs supervised by non-EU technical workers. Similarly, green increased demand occupations are lower-skilled and few in number. Non-green jobs have diminished but are still required to generate energy and fuel transport. Due to the failure to address climate change, and the lack of EU leadership in green technology, the labour market, and its skill requirements, look traditional with little impact from green jobs.

The green skills system is impacted by these changes. Universities have fewer admissions for green skill courses. The qualification regulation and standards of green and other professional, research and technical staff are governed in non-EU countries. Reductions in the demand for green and non-green medium and lower-skilled jobs in many sectors mean VET providers compete for fewer students. There is also a reduction in the demand for upskilling. VET providers respond by increasing the amount of online learning they deliver which reduces the quality of their provision as well as the number of tutors they need. As green technologies are jobs are being developed elsewhere there is an increased demand for distance learning to

[18] Green New and Emerging Occupations: these are occupations that have unique requirements for working in or on the decarbonisation of goods, processes and services, such as electric vehicle power unit designers.

[19] Green Enhanced Skills and Knowledge Occupations: occupations that currently exist but require a change in their competencies and/or context for working in or on the decarbonisation of goods, processes and services e.g., maintenance of electric vehicles (EVs).

[20] Green Increased Demand Occupations: those occupations whose demand is increased due to the decarbonisation of goods, processes and services, but do not entail significant changes to their competencies or context e.g., example electric power line installers.

[21] All other occupations, such as, those related to fossil fuel extraction, transport, processing and use eg in power generation.

meet the requirements of green jobs in other countries. Some students are duped into signing up for low-quality online training which does not lead to a job.

Key take-away for current policymakers derived from Scenario C
Man-made climate change is the greatest and most pernicious challenge that the World has faced. If not addressed, it will significantly and adversely affect every aspect of our lives.

In this scenario, the majority of green jobs in Europe are not high-skilled or high-quality jobs. *How can VET and skills policies support these medium and low-tech jobs*? This will be relevant in any scenario, but especially here.

6 Green leapfrogging: Old, mismatched Europe surrounded by new green giants (Scenario D)

Key dimensions:
No EU leadership in green technologies.
The environment is doing better.
High demand for green skills.
Lack of green skilled workforce, the supply does not match the needs.

Figure 5. Green leapfrogging.

Source: AI-generated with Dall-E.

In brief:
In 2050, third countries and regions have leapfrogged leaving Europe behind. The world has seen geopolitical shifts, but also an improved environment. Young people leave the EU to work in countries with positive green agendas. Lack of European leadership also results in the transfer of European companies to other regions, limiting the effective control of the European political and economic systems. Countries within the EU begin to align themselves with non-EU green leaders rather than promote unity within Europe. Skills systems are out of sync with global developments, where strange new demographic combinations arise to match old and new skills gaps. Since most green technology products are produced outside Europe, there is an increased focus on providing goods and services that are not technology-driven or mass produced (e.g. bespoke wine and cheese). Towards 2050, EU is in 'catch-up mode' trying to restructure the economic and skills ecosystems towards modes more aligned within planetary boundaries and with the green, global development trends.

How did we get here?
The urgency of IPCC calls to reduce carbon emissions in the 2020's and 2030's, coupled with the increased hyper-intensity of severe and unpredictable weather events caused by climate change, made China and India in Asia, followed by many countries in Africa and Latin America, to take actions that have led to positive environmental change. A 'Global South Green Deal' (GSGD) led to unexpected and large-scale cooperation that allowed economic activity to flourish without increasing emissions globally. Emerging economies led the development of sustainable, low-cost green technologies and environmental responses that were appropriate for the majority of the world's people. Building on an ethic of co-operation rather than competition, youthful communities across the global south[22]. took ownership of positive environmental change. They mobilised digitalisation and leveraged, their advantages with raw materials supply, indigenous knowledges, and community relations; leading climate-neutral technological and social innovation on a grand scale - never seen before.

At the same time, the European region ended up delaying the EU Green Deal, and the EU's visioned achievements were not met until much later. With the progress elsewhere and the delays internally, Europe squandered its chance of being a leading climate-neutral continent, and the region failed to become part of the global cooperative movement to reduce environmental damage.

[22] Some important countries in the Global South are by all accounts likely to be ageing in 2050 (most notably China, see e.g https://asia.nikkei.com/Spotlight/The-Big-Story/China-s-aging-population-threatens-a-Japan-style-lost-decade). Still, the youth population across the Global South will be remarkable in the decades at least until the 2040s. 37% of the population in Least Developed Regions and 27% of the population in Less Developed Regions were aged 0-14 in 2022, according to https://www.unfpa.org/data/world-population-dashboard.

Key drivers

Environment
While climate change is still a factor, given the 50-year+ impact window of the high level of carbon emissions in the 2020-2030's, significant progress has been made in reducing the negative effects of unsustainable twentieth-century development models and trajectories. A 'rooftop solar power revolution' has taken place in the energy sector, green hydrogen is being produced by numerous global south countries, and communities everywhere are aiming to do more with less. While battles still rage in response to hyper-intense weather events and associated infrastructural damage, more sustainable technological innovations more attuned to 'nature-based solutions' are being put in place. Innovations around local democracies, local economies, and recycling, reducing, reusing, and regenerating are at their peak - and considered 'normal culture' for most of the world's people. Children and young people focus on environmental care and the replenishment of biodiversity, cleaning up rivers and reducing plastic pollution. They grow up with a strong environmental ethic. As a result, ecosystems begin to replenish and recover from the worst of the twentieth century's fossil capital impact and lock-in pathways.

Work and Learning
By and large, up until 2050 European actors have failed in adapting the workforce for the demand for green skills. For decades, the region's stakeholders interpreted green skills narrowly as technical proficiency and failed to link this to social innovation and social and cultural change in society. Elsewhere, 'social skills ecosystems for just transitions' emerged, led by young people in the global south, who got tired of being excluded from mainstream education and learning systems. The younger generations had already had enough of colonial education and training approaches, including efforts in the 2000s-2020s to 'transfer green technology' and 'green skills' to the global South. China aligned itself with this global shift. The innovation and drive towards social and environmental change adopted by the youthful populations across the globe, and their collaborative ethos, moved the social ecosystems for skills forward. Indian skills development, learning platforms and accreditation systems started to dominate the world around 2031, and African youth were also strongly engaged in co-creating new skills ecosystems to serve their communities and to strengthen 'leapfrogging' approaches to economic and environmental change. Since Africa now was home to half of the world's children, this provided a strong, emerging and youthful movement for ongoing change, attracting interest from some progressive EU countries.

With the strong collaborative foundation established by the GSGD, some international partnerships for green skills sharing and collaborative learning have emerged by 2050, for example between the African Union and the European Union. Now, international actors are looking to provide education export to European countries. Within the skills ecosystem approach, education institutions and communities are working together to establish interesting and viable work and learning pathways for youth, as well as more mature members of society, including the ageing populations in the EU. More flexible models of accreditation are now the order of the day as qualifications 'stacking' becomes the norm, rather than the older reliance on over-structured, linear learning pathways. Cooperative learning approaches are also emerging as a key feature of green skills and companies.

Demographics, lifestyles and values
Inspired by the evident environmental changes and social innovations, and by the youthful drive and energy of African, Asian and Latin American youth, young people in Europe leave the European Union to work abroad in countries with positive green agendas and societies that are shaped by dynamism of community relations, rather than individualism. With the emerging collaborative ethos globally, and efforts to include the EU in the global just transitions movement, there is a hope that some of these will return with new skills and help boost the flailing economies of Europe.

By this time eco-wellbeing is considered the goal of European populations. Climate justice, animal and plant rights are fundamental to majorities of voting populations as they see the benefits of such approaches in other parts of the world. Due to the neglect of green skills in the 2020's – 2030's, strange new demographic

combinations arise to match old and new skills gaps, mainly because young people are moving to find more interesting spaces where green skills development is flourishing in better environments.

Economy
In Europe, a heavy emphasis on 'growth' and one-dimensional views on GDP has dominated, while elsewhere countries have implemented new measures of 'growth' which include well-being of people and environments, not only wealth creation for the few. The fundamental structure of the global economy is by now geared towards cooperative economies that reduce the wealth gap between the rich and the poor, emulating early successes of the EU's welfare states in the 1970s. In 2050, Europeans finally want to be part of greening the world, but Europe experiences a significant skills mismatch: There is a high demand for green skills, but the workforce does not match the need in countries inside the EU.

Governance
The lack of EU leadership has seen the more progressive countries in Europe align themselves bilaterally with countries outside the region. 'Progressive' countries have long thought that they have more in common with leading green countries than their fellow Europeans. Many European companies have moved their headquarters elsewhere. This has further diminished European strategic autonomy.

Technologies and social innovations
Europe is a follower, not a leader, in green technologies and innovations and social innovations that accompany the cooperative approach to environmental change elsewhere. Intellectual property rights (IPR) and regulations and standardization are led by other parts of the world, and there has been a shift away from privatising IPR to sharing IPR in the global knowledge commons. A global knowledge democracy has emerged to drive the just transition to sustainability, and the EU finds its ongoing attempts at IPR control to lack traction in the international sphere.

Europe is using foreign technologies at an additional cost that further harms EU's competitiveness. Europe runs a remarkable trade deficit, and the region is now part of the supply chain for countries in the Global South (e.g. BRICS-countries).

Green skills and green jobs:
The EU skills system is out of sync with the international trajectory towards securing a just transition for all. Due to the lack of investment in the EU Green Deal and its earlier ambitions, skills system actors have not planned for, nor provided for green skills. There are a few exceptions, but the skills system is still providing skills for a 'dinosaur' economy. The skills system and its assessment methods continue to emphasize individual competitiveness over cooperation. It also primarily offers linear learning pathways into traditional non-green industries. Patriarchy and military-industrial style thinking drives skills system logics and programming. Single disciplines are still strongly emphasized, with 'hard sciences' still dominant in the technology sphere. There is little integration between the STEM and social sciences. Feminist, decolonial and cooperative approaches are nowhere to be seen.

Specialisation in 'old spheres' hampers innovation, and there are few transdisciplinary learning labs for social and technical innovations oriented towards green skills development. Examination and accreditation systems are also rigid, and there is no recognition of courses and qualifications offered elsewhere (e.g. from India or Africa) as historical dispositions do not allow EU skills system actors to recognize excellent knowledges and innovations elsewhere. There is almost no investment in the training of academics and lecturers, especially vocational education and training lecturers to advance their knowledge of just transitions, green skills, green and circular economies, and co-operative economies.

With the ageing populations in the EU, this presents as an important challenge as skills are mainly typified to high-tech skills. The skills ecosystem lacks agility to design and develop technologies that are in demand in the global South, thus they become rapidly irrelevant in the larger global sphere. There is a heavy reliance on young engineers from global South countries, but these have little interest in moving to Europe. They are also better paid in their own countries. European companies thus find it exceedingly difficult to attract international talent.

An ’emergency plan’ for EU green skills development, which arouse in 2045, requires large new investments in appropriate technology development aligned with the global trend towards just transitions for all. The purpose of the plan is to turn the tide, finally, by offering expensive bursaries and establishing strong collaborative training programmes with countries in the global South and investing in major skills system overhauls. To catch up with the leapfrogging of the rest of the world with green technologies, the main demands for green technology development are:

- Energy, with the emphasis now on smaller scale renewable energy units that can be community controlled or that can service industrial ecosystems;
- Construction, with emphasis being more sustainable designs and materials that are less extractive and destructive;
- Circular economy development in which a core ethos of ‘doing more with less’, ‘sharing more better’, and ‘re-using multiple times’ drives more cooperative economic interventions (e.g. vehicle sharing schemes) that benefit more people more equitably. Overall the direction is towards achieving Zero Waste and Zero emissions, even though this is still a challenge, especially in the transport and manufacturing sectors.
- Agroecology, ecological infrastructure and sustainable water management and biotechnology research is now prioritized to adopt nature-based solutions, and smaller scale operational spheres that are more inclusive and that don’t damage biodiversity or catchments; rather the emphasis is on regenerative agricultures, biotechnologies and landscape management

New working conditions emerge in which communities form working co-operatives and share profits and wealth within and between them at different scales. New models of skills development emerge, including social ecosystems for skills in which informal and formal training programmes interface, and learning pathways become more flexible. Apprenticeships, combined with formal learning programmes offered in diverse modes (e.g. blended, hybrid, online, face-to-face) gain new traction, and young people learn to earn in more collaborative ways supporting each other across national boundaries, and through innovative communications systems and learning platforms.

Key take-way for current politicians derived from Scenario D
The world, in this scenario, is shaped by young generations in emerging economies, and by the relevance of affordable low-cost green technologies.

How can Europe develop green skills collaboration with other countries to mutual environmental and societal benefit, and to serve the just transition that is needed for all, across the planet?

7 Cross-cutting policy implications

Each scenario depicts a different future for the state of green skills and jobs in Europe. Scenario A depicts a world with improved environmental conditions, and in which Europe is at the forefront of providing solutions. Here, the biggest challenge related to green skills and jobs is the provision of green-skilled workers in Europe to meet the strong demand. Scenario B portrays a polarised society in which the global environment is doing worse, although Europe plays a leading role in global green technology. A major challenge in this scenario is to reduce the skill divide and transfer knowledge from large corporations to SMEs. Another is to secure long-term skills development in a resource-strapped, short-term thinking world. In scenario C, the high-skilled European workforce has emigrated or is left behind in a non-green world. The environment is doing worse, and so is the European labour market. Since most green jobs are in low-tech professions, the key skill challenge is tied to ensuring a broad VET base that can rapidly 'bolt-on' new skills. Finally, in scenario D, the global environment is improving, but the EU is becoming marginalized in a green, multipolar world. Here, the green skills challenge relates to modernising and internationalising training systems and making sure that Europe does not become too insular.

Each scenario has its implications for research and innovation policy. Consequently, further to scenario-specific policy implications, we derive the following cross-cutting implications from the scenario narratives and the workshop discussions:

Our shared understanding of what green means is reconfigured over time.
A pathway suggested in the several scenarios to a less attractive future in 2050 was based on an overreliance on (future) technological solutions as the main option to fix environmental problems. Looking back from 2050, either these solutions never arrived at a sufficient scale, or they turned out to be only partial solutions and less green than originally envisioned.

We do not know for sure what present technologies and practices humans will, looking back from the future, regard as green. People in 2050 will likely look with a negative lens at what we might now classify as green jobs in 2023, or for that matter what they will consider as green which is not considered as such today. This also implies that we must be humble in assessing the state of green skills and jobs in 2050, as we must assume a different understanding of greenness by then.

- *Future R&I policies should pay sufficient attention to how the understanding of green and sustainability changes over time. It is recommended to develop policies and practices for continuous monitoring, reassessing, and updating of existing and emerging policies, practices, and technologies. When designing research and innovation initiatives with a time-to-market of at least 5-10 years, R&I policymakers must try to sense ongoing changes to the definition or perception of what is green and attempt to anticipate near-future value developments. Strategic foresight can help pick up such signals.*
- *As the understanding of green changes, the skills ecosystem for green skills needs to be continuously reconfigured. This requires resources and political attention to the need for adaption.*

A separate aspect of this challenge is that many solutions may be considered green only insofar as they are not overused or used by too many. For example, too many electric vehicles on the roads lead to congestion, and an exponential development of the reliance on ICT solutions creates pressures on energy systems.

- *R&I policy could focus on demarcating green 'corridors' - inspired by doughnut-thinking[23] or planetary boundaries - with both minimum and maximum thresholds of 'greenness' and green applications. In particular, it might be challenging, but important to open discussions on how R&I policies could be implemented with specific aims of understanding the limitations of so-called 'green' solutions.*

[23] Cf. Raworth, K. (2017) *Doughnut Economics: Seven Ways to Think Like a 21st-Century Economist.* For some information on EU initiatives along these lines, see https://doughnuteconomics.org/stories/29

Given the challenges of knowing what is really green the futures also imply a bigger emphasis on *deep sustainability* over technological solutions when it comes to creating a green-skilled Europe in 2050. With their reluctance to rely on technology alone, the narratives also highlight the importance of an R&I policy that supports inter- and multidisciplinarity, and which consistently integrates multiple perspectives (e.g. social, environmental, cultural) in addition to the technological. R&I should be collaborative, holistic and diverse to avoid blind spots.

- *Collaboration between various fields such as engineering, environmental science, social sciences, and policy development are essential to address the complex challenges of sustainability. R&I policy should reflect this.*

There will be no green transition without a strong, VET-trained skills base.
An important connector between all scenarios is that future green jobs in Europe are not only high-skill jobs. Implementing the green transition and adapting to new environmental conditions require retrofitting of buildings, a green society requires strong waste management, and a circular economy necessitates repairing and repurposing skills. These are just a few among many examples. Furthermore, swift reactions to climate-change related events likely require much more than technology-oriented jobs.

This leads to the common conclusion that an STI policy supporting future green skills and jobs in Europe addresses not only frontier scientific and technology research but rather emphasizes the important role of vocational training.

Especially, if conditions change faster in the future due to e.g. digitalisation, geopolitical instability, and weather-related disasters, the adaptability of VET is paramount for societal resilience. Appropriate skills and training is also important for the quick application and dissemination of (social and technical) sustainability innovations.

- *Strengthening VET and VET systems should therefore be an important part of European STI policy to support the green transition.*

In developing green skills (including 'bolt-on' skills, as described below) there is a need to develop a VET ecosystem that includes all aspects of skills development: formal, non-formal, and informal; and technical and social skills. Assessment and accreditation, as well as delivery, need to accommodate this wider and more flexible skills acquisition process.

Since societal needs change, and since the understanding of 'greenness' is moving, it will also be required to **prioritize skills monitoring and adaptation**. This should not be interpreted such that each job - or change of job task definition prompted by external change - will require entirely new skillsets. Instead, it is assumed across the scenarios, that many future green jobs will require certain social and technical skills as a base and specific 'bolt-on' skills for particular job- requirements. This also underlines **the role of life-long learning** as an important supporting structure for green skills and, ipso facto, the green transition. Unless people in the workforce are able to take on new skills for new types of jobs and/or able to swiftly master new functions in response to shifting environmental requirements (or perhaps even as a response to environmental disasters), both environmental responses and labour market responses will likely be suboptimal.

The scenarios pay a lot of attention to the perceived risk of increased polarization in society. At the same time, they underline that the population working in green jobs cut across many economic sectors and job types. Perhaps one message could be that policymakers need to be better at **talking up the critical 'green' contributions of many traditional occupations** from waste collection over bicycle repair to forest stewardship. Articulating 'green jobs' as something new and, by definition, safe and well-paid might be doing the green transition a disservice, if it alienates important sectors of the labour market, and if its implication is that not enough attention is directed at skills development at this 'lower end' of the workforce. It is therefore seen as an important countermeasure against polarisation to provide knowledge on green skills, technologies, and solutions to a wider audience.

Another important implication is that innovation policies should also **stimulate low tech, easy-to-adapt solutions**. Several scenarios perceive as plausible a growing gap between large companies well capable of adapting to new (green) technologies, markets, and regulations, and SMEs with limited management, leadership, financial and HR resources falling further and further behind. Similarly, there is a sketched divide between green solutions that generate significant corporate profits and green solutions that do not – with a risk that such 'ordinary' solutions are not deployed to the effect that they could be. R&I policy could help address this market failure gap. Similarly, support can be developed for SMEs during the green transition. Policy could also stimulate the development of relationships across businesses of all sizes (including start-ups) within supply chains, through mentoring and buddying systems, and through geographic and sectoral business support networks. These relationships include skills and workforce sharing e.g. larger firms sponsoring apprenticeships in smaller firms and sharing their workforce development resources (e.g. management development intranets).

Grow the base for green skills and jobs. There is a need to address gender imbalances[24] and issues of diversity, inclusion, and vulnerable groups within the green job labour market. This need is made stronger by the long-term demographic forecasts indicating fewer working-age Europeans in 2050. Greater green skill inclusiveness should be a target both in research settings (broadening the base of those working with green R&D) and in the wider labour market, suggesting the need for initiatives both in R&I and in VET policies.

Green transition requires European and international cooperation also in R&I policy.

The scenarios also point towards the need to foster international collaboration across all levels: national, regional and sub-regional government, NGOs, community organisations and private sector businesses across all aspects e.g. research, development and innovation; workforce development; initial VET development (student exchanges); skills provision.

- *European R&I policy should support and underpin international collaboration on green skills provision. Such collaboration will be mutually beneficial: Advancing the green transition globally, stimulating green job growth, and ensuring a strong European link with global skills ecosystem development.*

Across scenarios, we identified the insistence that open science, new more open models for IPR, and collaborative modes of research will lead to greater transparency and potentially greater societal benefit globally. Especially in scenarios, where the European development looks a bit more dire, the recommendation not to turn too much inwards or to abandon the ambition of open science and open collaboration is important.

Green development paths are shaped by emerging technologies; emerging technologies should also be shaped by green skills.
The nature of technological development is one of the unknowns across all scenarios. There is a sense that a new 'age of AI' could fundamentally shift humans' roles and functions in the future labour market. While overreliance on technology was seen as a potential explanation for less wanted future outcomes, there is a distinct need to consider how digitalisation and sustainability interact. Some digital technologies may have potential sustainable benefits for society, but development and deployment are hindered by a lack of market incentives. An example could be increased automation of the lowest paid jobs or the adoption of AI solutions in agriculture or industry that would provide environmental benefits at a (low) cost for the producers. It is easy to imagine many such examples of market failures where investments that are positive on the societal level are not carried through. Public support, including for R&I, should help address such

[24] Across OECD countries and regions, 72% of green jobs are currently held by men. See OECD (2023), *Job Creation and Local Development 2023: Bridging the Great Green Divide*. Some forecast already indicate long-term changes to this situation though, see CEDEFOP (2021), *The Green Employment and Skills Transformation: Insights from a European Green Deal skills forecast scenario*, p. 24.

market failures. At the same time, while it is a possibility that AI and other digital technologies will lead to more green societies, it is by no means guaranteed. Policies are important for steering this direction.

- *It is recommended to integrate green skills and concepts of greenness in the technological development of **emerging technologies** and in orchestrating technological uptake.*

Annex 1: Policy implications of each scenario

Policy implications of Scenario A for today

This scenario emphasises the importance of local initiatives that are in line with an EU-wide vision of maintaining leadership in green technologies. The budgets at the Member states for research and innovation are partly distributed among research institutes at the regional and local levels to focus on their specific areas of expertise. Much of the EU budget is used to promote and facilitate collaboration among European researchers. Furthermore, the EU regulates the provision of an access-for-all lifelong learning infrastructure to ensure green skills development among European workers.

Future developments in the scenario	R&I policy implications
Society and environment	
The European society has undergone a significant shift towards sustainable and environmentally conscious living. There is a strong support for sustainable products.	Current European R&I policy should support this shift, e.g. by developing coherent policy measures for advancing with circular practices, producer responsibility, product service systems, etc., and engaging all actors, including citizens with lifestyle changes.
Expertise is needed for renewable and nuclear energy production. Technicians are needed who are knowledgeable on solar, wind, hydro, and other renewable energy sources, as well as nuclear energy sources, including the design, installation, maintenance, and optimization of renewable energy systems.	Current R&I policy can advance this by funding research and strengthening education in areas such as renewable energy, eco-friendly materials, sustainable agriculture, and waste reduction technologies as well as research in electric vehicle technology and efficient public transportation systems.
Technical, green expertise is needed on energy usage in buildings and industries, energy savings initiatives, and energy-efficient designs. These skills are also important for architects and designers who need to be focused on creating energy-efficient, sustainable buildings and urban spaces.	Today's R&I policy can e.g. encourage educational programs for energy efficiency specialists and develop mechanisms that support widespread uptake, e.g. by addressing a wider workforce than just engineering specialists. Coordination across member states could be organized by the EU.
In 2050, health is considered a part of sustainability and therefore also of 'green'. Given the aging population, geriatricians and healthcare professionals with expertise in age-related health issues are in high demand.	Several countries already experience shortages of health care professionals. This is perhaps only exacerbated in this scenario. Present countermeasures could be to a opt initatives to attract and retain more health care professionals. In addition, it can be considered to a dapt educational programs for health care professionals to address how to cater sustainably for an aging population. Links between green and health, e.g. in the context of a bigger focus on prevention rather than treatment, can be examined to a wider degree.
Demographics, lifestyles, and values	
European regions with a strong green economy and abundant green job opportunities are experiencing increased immigration, as people from other regions (also from outside the EU) seek better employment prospects. Conversely, areas with fewer green job opportunities are experiencing emigration.	The EU and MS could instigate a new 'green skills for migrants' programme**.**
Sustainable lifestyles have become the norm in 2050.	To support this shift toward sustainable lifestyles, R&I policy may contribute to the development of smart cities and infrastructure. This would include innovations in urban planning, clean energy infrastructure, and technologies that reduce waste and energy consumption in urban areas.
Education	

Education and training programs have adapted to new green and digital realities.	Current R&I policy should facilitate this adaption. Some measures could be to develop incentives for national universities to design educational programs that include a strong emphasis on digitalisation (e.g. AI, data science, omics, and bioinformatics) especially in the context of green technologies, and to develop incentives for national universities to design educational programs that focus on environmental skills, sustainable building techniques, and climate adaptation skills, such as distress tolerance, resilience, and recovery.
Continuous learning, reskilling, and upskilling will become essential to keep up with changing job requirements.	It is a premise of this scenario that employer success is shaped by the ability of attract workers who are able to quickly adapt to new job requirements. The EU can help support this lifelong learning e.g. by developing an EU-wide (online, lifelong learning) system for the provision of education and by developing incentives for employers to invest in green skills and green education provision.
Need for sharing of knowledge, data, and insights among researchers/students, and accelerate innovation.	The EU can support this via promoting living labs serving as educational platforms, providing opportunities for students, researchers, and professionals to gain practical experience in innovation and research.

Policy implications of Scenario B for today

In this scenario, which is structurally marked by strong contrasts resulting both from environmental constraints and from political and economic choices, the policy implications relate above all to the possibilities for transferring knowledge and resources from large and prosperous green technology companies to companies working in other sectors, struggling to grow and experiencing serious economic difficulties.

Future developments in the scenario B	R&I policy implications
Economic policy	
There is a strong polarisation between large, export-oriented green technology companies and small companies supplying the waning domestic market.	To avoid such a polarisation between large, incumbent companies and emerging SMEs, makesure that the financial benefits granted to green technology companies is conditional on the development of processes and products that can be used also by smaller companies. This particular outcome also seems fuelled by a gap between environmental requirements inside Europe and on the global market. Such a gap – with lesser standards in Europe - should be avoided.
Small companies whose production is geared towards the domestic market rarely use green processes (mainly due to a lack of resources).	Policies can alleviate SMEs' challenges regarding uptake of green processes. Targeted measures could be based on where the development and implementation of these processes would be the easiest and most profitable.
Small businesses (often cooperatives) have developed in the recovery, recycling, and repair sectors, etc.	Policy initiatives can accelerate these positive developments e.g. by helping set up a platforms and networks within which exchanges and cooperation on the development of good practice can be built.This would make it easier for smaller green businesses to thrive and grow, despite challenging conditions in this scenario.
Preservation of infrastructure, housing, landscapes, farmland, etc., in the face of natural phenomena linked to climate change.	Some of the new environmental damages befelling Europe in this scenario have already been felt in other parts of the world. To limit the economic and environmental damages, European R&I policy could pro-actively support information-seeking on know-how and technologies from outside the European Union. Learning from the experience of others could help disaster preparedness.

Technological support	
Many workers have several activities, often including small-scale farming, to generate enough income to live on. Farming is subject to extreme weather conditions.	Policies should help ensuring that part-time farmers have access to cultivation methods, seeds, and tools that enable them to ensure a minimum harvest. The pooling of certain equipment can also be encouraged.
In this scenario green solutions have become the forte of private, for-profit companies, while state capacity is low. This entails a risk that green solutions that do not generate corporate profits are not developed or deployed at scale. At the same time, resource-strapped citizens do not use green technologies (or only to a limited extent) in everyday life because of their costs.	To help avoid this scenario, R&I policy could stimulate aid for the development and use of low-cost low-tech solutions (even if their efficiency remains lower than that of more sophisticated techniques).
Given the hazards associated with climate change, the price of raw materials and energy has risen, representing a heavy financial burden. What's more, their availability is not always guaranteed.	Policies could stiulate networks at the local level to optimise the use of raw materials as part of a circular economy, in particular, so that the by-products or waste of some become the raw materials of others.
The economic operation of the smallest businesses (not to mention their development) is hampered by the difficulties of maintaining infrastructure, which is a victim of climate change.	If the environmental damages become very frequent, policy planning should address how infrastructure can be made more resilient, and how to help SMEs rebound from natural disasters. Disaster managent, rebuilding, and resilience would become core green skills, and skills training should help emphasize and develop those skills.
Training	
Many workers are poorly trained, due to a lack of resources and insufficient job opportunities.	Setting up training courses to provide all workers with a common base of general and technical knowledge, with particular emphasis on the greening of the economy. This knowledge will then enable them to acquire more specialised skills.
Over time, the deterioating education of the majority of the population would likely also have negative spill over effects for the green technology sectors. At the same time, the green technology sectors would have a lot to offer for the rest of the economy.	Establishing partnerships between green technology companies and specialised training centres to provide the latter with training resources in green trades and techniques.

Policy implications of Scenario C for today

Future developments in Scenario C	R&I policy implications
Skills policy	
Lack of Government consensus and resources on green responses means that longer-term planning is not possible and only short-term responses are feasible. These are mostly driven by the need to limit the impacts of climate change and related disasters, and the immediate demands of green technology employers, most of which are based overseas. i	Current policies could take measures that would help minimize the risk of falling into the trap described here. Measures could be e.g. to improve short-term skills programming to enable fast responses to the impacts of climate change. For example, focusing on transferable skills that underpin a range of occupations and can move people quickly into new job roles. Also, identify which 'bolt on' skills are required that can be added to existing competencies in similar occupations so people switch to meet new green enhanced job demands.
There is an increase in community-based, social innovation and low-tech green projects as well as, and self-development and well-being to cope with the impacts of climate change.	In a very negative scenario, these green elements provide positive exceptions to the general sentiment. R&I policy could help support even such scattered green community initiatives by e.g. seeking to: Encourage community development entrepreneurship and management skills e.g. creating and managing co-operatives and social enterprises. Develop skills programmes focusing on low-tech green projects, for example, growing your own food, repairing consumer items, home insulation, and ventilation. Develop well-being and self-development skills so people are better able to cope with the damaging effects of climate change, and identify personal solutions.

The lack of green skills demand means that formal green skills provision in the EU has been reduced. High-level green skills demand is now in non-EU countries.	In the situation where European workers interested in high-level green careers will need to go abroad to fulfill their dreams, career services can help identify international high-level skills needs and routes to them. In the case where most European talents have migrated out of the region for career reasons, EU science policy could consider large-scale programmes incentivising returning expat scientists.
Labour market	
Most green jobs are medium or low-tech jobs.	In this scenario, most green jobs are precarious and in low-tech professions. At the same time, many holding those jobs might have their own low-tech green work (e.g. growing their own food, repairing bicycles in the community) at the margin of the labour market. Policy initiatives are encouraged to make it easier to accommodate such formal and informal jobs at the same time and also to encourage employers to recognise non-formal and informal skills accumulation and accreditation.
Research and innovation	
The EU has lost leadership in the development, deployment, and utlisation of green technologies.	Several policy initiatives might be considered to avoid this loss of gobal competitiveness in R&I: Focused analysis and investments on what needs to be done to regain the EU's seat at the top table of green research and innovation (R&I). Developing 'moon landing' green technology projects to concentrate financial and RDI resources on climate change solutions and develop spin-offs. Tax investments in all fossil fuel development and use to invest in green technology investments.
Bottom-up development of community-based low-tech green solutions.	Policies can support this by recognising that combating climate change includes low- as well as high-tech solutions, and supporting the development of low tech green solutions. As the technology is well known and understood, the focus is on innovative ways of organising, supporting, and resourcing its adoption and implementation at a community level.

Policy implications of Scenario D for today

This scenario is characterised by regression and neglect of investment in the EU Green Deal and appropriate green skills and green jobs in 2025, and a positive leapfrogging of green technology development and social innovation in other parts of the world between now and 2050. These dual developments leave the EU 'behind' in the green technology revolution. Moreover, it raises the question of how the EU Green Deal is framed in relation to the external environment beyond the EU, especially in relation to the burgeoning youthful populations in the Global South and their ambitions and need for a just transition for all. It warns about a narrow inwards focus of the EU Green Deal. Inadequate international scanning and lack of international partnerships could lead to a mismatch of European and global green skills ecosystems and demands in 2050, leaving the EU in 'catch up' mode.

Future developments in the scenario D	R&I policy implications
Economic policy	
Despite positive environmental change elsewhere, the EU economic policy remains focused on sunset, non-green industries, failing to engage adequately with climate change implications, green skills and a just transition to sustainability for all.	The scenario depicts the risk of being locked-in to incumbent industries. Policy measures supporting economic diversification and shifts to new, less-polluting industries should be in place in due time, for example with the identfication of short, medium and long term interventions that would help address potential damaging lock-ins.
EU Green Deal policy may be too inwardly focused, lacking engagement with changing geo-political trajectories and alliances elsewhere (BRICS, the Global South).	Further attention is need to position the EU strategically in the global efforts in green transition. For exampe, strategic foresight could be used to develop clear analyses of

	changing geopolitical relations and their implications for the green transition.
Benefits of Open IPR and collaborative economic models remain under-developed for their transformative potential in the green revolution as emphasis remains narrowly focused on technology competition and patenting.	The logic of the scenario is that open cooperation over time will become the norm and that it will be risky to close off from this development. Here, the EU would benefit from setting up pro-active approaches to Open IPR that advance knowledge democracy for the green revolution and just transitions to sustainability for all, beyond narrow national or regional interests.
Information	
In an inwardly facing EU trajectory that fails to lead the green revolution in ways that advance a just transition for all, EU may be 'left out' of major international trends seeking to address climate injustice and global sustainability.	Initiatives might be devised to risk ending up in this situation: Identify and communicate new trends influencing green and just transitions timeously to all stakeholders. Avoid technological and institutional lock-in to one trajectory (i.e. ecological modernisation), and broaden the scope of green technology development (i.e. not just high tech, high cost, but also low tech, low cost and nature-based solutions)
Technological support	
Despite massive green technology development of all kinds (including low cost, low tech and nature based solutions) elsewhere, technology development in EU remains in lock-in mode.	In this scenario, the success of green technologies and solutions will be determined by their ability to lift up global populations. The EU can seek to strengthen their relevance for this target group by supporting the development of infrastructures for a wider range of green technologies (not high tech, high cost solutions only, but also low tech, low cost and nature-based solutions). This will require bringing STEM, humanities, and social sciences closer together.
Import of green technologies from elsewhere becomes the norm, with loss of early advantages and early uptake of new innovations, and with the additional cost of importing.	Establish strong structures and partnerships with technology-developing, emerging economies to ensure collaboration and partnerships. Increase strategic trade arrangements and technology transfer (inwards and outwards).
Training	
There is an emerging demand for green skills, but there are not enough skills for the demand. The European green skills system is out of sync with the rest of the world.	To avoid this, ensure that European skills systems remain up to date (anticipatory actions on skills demand). Consider alternative models of skills development (e.g. lifelong learning systems and social skills ecosystems that align formal and informal skills development paradigms) and more flexible assessment, accreditation and delivery models. Take education of researchers in environmental ethics and social justice principles into consideration for science, technology and innovation (STI) policy-planning.
Young people leave Europe to learn green skills in other parts of the world. The EU struggles to attract talent from other countries due to climatic, financial and ethical reasons.	To make or retain Europe as an attractive region for work, pro-actively put in place high quality, attractive and relevant training programmes for green skills, broadly addressing key areas such as energy, transport, sustainable food systems, manufacturing, biodiversity and landscape management, and co-operative and sharing economies.
	If this scenario starts to unfold, there is a strong risk that there will be pressures for European universities, scientific communities, and VET systems to become more inward-looking. This pressure should be resisted, and instead Europe should integrate into new global realities. This can be helped by investments in green career guidance programmes and encourage systemic investments such as bursaries and knowledge exchange opportunities for green career development.

Annex 2: Factors of Change

Environment

- Climate Change
- Declining biodiversity due to human activity
- Increasing shortages of water and poor chemical status of groundwater
- Ocean temperature rising
- Acidification of oceans and waters
- Land degradation
- Conflicts over renewable energy installations on land and sea
- Pandemics and epidemics
- Rewilding
- Land restoration
- Future farming
- Nature-based solutions

Work and learning

- Types of employment
- Use of new technologies in vocational training (initial and continuing)
- The role and nature of vocational education in initial training
- Financing vocational training
- Service-based leadership models

Demographics, lifestyles and values

- New modes of consumption: The sharing economy
- Migration, immigration and integration
- Anti-science movements
- Anti-consumerism movements
- Conflicts over procurement of natural resources, e.g. through mining
- Conflicts over use of natural resources
- Prosumerism communities
- Demonstrations and other forms of civil activism
- Natural and cultural heritage
- Rural lifestyles increasingly idealized
- Shift towards sustainable diet
- Demographic shifts
- Inequality
- Polarization
- Community stewardship
- Reframing residence

Economy

- Availability of natural resources (excluding energy)
- Relocating production to developed countries
- Development of the digital economy
- Solidarity economy
- Circular economy
- Globalisation pressures
- Diversification of rural economy
- Threat of declining economic activities due to sea and land use
- Mining and quarrying

- Tourism
- Transport
- Land grabbing
- Land abandonment
- Stranded assets
- A race to fill the world with green devices
- Distributed manufacturing and production
- Greenflation

Governance

- The economic influence of state structures
- Property insurance and risk prevention
- Shifting towards multistakeholder governance models
- Co-management for sustainable common pool resources
- Co-operatives and partnerships
- Political myopia
- Emission trading systems
- Geopolitical shifts
- Deglobalisation and friendshoring
- North-South global relations
- Rights of future generations
- Greening through regulation
- European cohesion
- Disequilibrium and mismatch of governance structures

Technologies and social innovations

- Traceability of goods and raw materials
- Changing the way goods are produced
- The construction industry
- Transport and logistics industry
- Reuse-Repurposing-Remanufacturing
- Remote sensors are increasingly deployed
- Increasing use of automation
- Artificial intelligence for all
- Collaborative robots
- Climate-resilient infrastructure

Annex 3: Illustration prompts

The four scenario illustrations have been created from Dall-E (October 2023) with the following prompts:

- *"Show a landscape that exemplifies "Green, technology intensive Europe" in the year 2050"*
- *"A photorealistic painting of a damaged European environment in 2050 inspired by the comment "apocalypse soon"*
- *"A drawing of a European cityscape in 2050 to illustrate a foresight scenario titled "feeling the pain", and in which the environment has deteriorated, and there is high unemployment. No text in the picture!"*
- *"An oil painting of the world map, with lots of green manufacturing facilities (e.g. wind turbines) in Africa Asia and South America, but just nature in Europe"*

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