Supplementary material

Cross-country expert profile

Table 1: Cross-country expert profile

Country / geographical scope	Research / Academia	Private sector	Public sector	Civil society
Spain	36%	48%	6%	10%
Germany	38%	25%	12%	25%
Portugal	33%	33%	11%	22%
Italy	50%	38%	0%	0%
Ireland	29%	29%	14%	29%
Hungary	0%	100%	0%	0%
European Union	25%	50%	25%	0%

Deductive coding

Table 2. Deductive coding framework

Category	Code (label)	Description
Niche level (emerging innovations)	Economic factors	Market dynamics, costs, and financial viability of innovations
	Governance factors	New governance arrangements, coordination mechanisms
	Social factors	Behavioural change, social acceptance, practices
	Technological factors	Emerging technologies and innovation pathways
	Political factors	Policy support and political prioritisation of innovations
Regime level (dominant systems)	Political factors	Existing policies, regulations, and institutional frameworks
	Economic factors	Market structures, cost systems, and financial constraints
	Social factors	Established norms, practices, and societal behaviours
	Technological factors	Dominant infrastructures and technological systems
Landscape level (macro context)	Political factors	Geopolitical dynamics and large-scale policy trends
	Economic factors	Macroeconomic conditions, energy prices, resource scarcity
	Social factors	Societal attitudes, demographic changes
	Environmental factors	Climate change impacts and environmental pressures

Vulnerability dimensions	Financial vulnerability	Limited capacity to afford transition-related costs
	Skills-related vulnerability	Lack of digital or technical skills
	Employment vulnerability	Exposure to job loss or labour market restructuring
Disadvantaged groups	-	Groups disproportionately affected

EU-level policy documents

- European Commission (2021a). European Industrial Strategy
- European Commission (2021c). Sustainable and Smart Mobility Strategy
- European Commission (2022b). European Growth Model
- European Commission (2022c). Energy and the Green Deal
- European Commission (2023d, 2024c). Digitalisation of the European Agricultural Sector
- European Commission (2023a, 2023b). Energy poverty frameworks and indicators
- European Commission (2023c). Pact for Skills – Renewable ecosystem
- European Commission (2024a). Access to transport for all
- European Commission (2024b). Fit for 55 – Delivering the proposals
- European Commission (2024d). European Green Deal
- European Commission (2024f). Transport poverty report
- European Commission: DG MOVE (2024). Transport trends and issues in the EU
- European Commission: Joint Research Centre (2023). Clean Energy Technology Observatory
- European Environment Agency (2024a, 2024b, 2024c). Transport, EVs, renewable energy indicators
- European Parliament (2022). Understanding transport poverty

National policy documents (by country)

Spain

- Ministerio para la Transición Ecológica (2024). Plan Nacional Integrado de Energía y Clima (PNIEC 2023–2030)
- Ministerio para la Transición Ecológica (2020). Long-term decarbonisation strategy 2050
- Ministerio para la Transición Ecológica (2020). Hydrogen Roadmap
- Ministerio para la Transición Ecológica (2019). Estrategia Nacional contra la Pobreza Energética
- Ministerio de Transportes (2021). Estrategia de Movilidad Segura, Sostenible y Conectada 2030
- Gobierno de España. Plan de Recuperación – Mobility component

Germany

- Federal Ministry for the Environment (2016). Climate Action Plan 2050
- Federal Ministry of Finance (2020). German Recovery and Resilience Plan
- BMWK (2023). System Development Strategy (energy systems)
- Federal Ministry of Labour (2022). Skilled Labour Strategy
- Bundesministerium der Justiz (2019, 2020). BEHG and GEG regulations (energy and buildings)

Ireland

- Government of Ireland (2024b). National Energy and Climate Plan (NECP)
- Government of Ireland (2023). Long-Term Climate Strategy
- Government of Ireland (2024a). Renewable Electricity Taskforce
- Department of Agriculture (2021). Food Vision 2030
- Teagasc (2022). Climate Action Strategy 2022–2030
- Irish Human Rights and Equality Commission (2023). Just Transition Policy Statement

Italy

- Italian Ministry of Environment (2024). National Energy and Climate Plan (NECP)
- Ministero dell'agricoltura (2024). National Organic Production Plan
- Ministero delle politiche agricole (2021). CAP Strategic Plan
- Italian Government (2021). Long-term emissions reduction strategy

Portugal

- DGEG (2019). National Energy and Climate Plan (NECP 2030)
- National housing and urban policy literature (Alves et al., 2023; Chamusca, 2024)
- Laranja et al. (2020). Smart Specialisation Strategy implementation

Hungary

- European Commission (2024e). Final updated NECP (Hungary)
- Ministry of Innovation and Technology (2021). National Hydrogen Strategy
- ITM (2024). National Battery Industry Strategy 2030
- Ministry of Agriculture (2017). Jedlik Ányos Plan (electric mobility)
- Active Hungary (2023). National Cycling Strategy 2030

Cross-cutting national and sectoral evidence

- European Commission CAP Strategic Plans (Ireland, Italy)
- European Commission (2023g, 2023h). Country factsheets (agriculture)
- European Commission (2021b, 2022a, 2022d). Construction sector country profiles
- Energy Poverty Advisory Hub (2023). National indicators

Summary table main drivers, risks, DGs and governance implications by sector

Table 3. Summary table. (Source: Armayones Carranza & Viñé, 2025b)

Sector	Main drivers	Key risks	Disadvantaged groups	Governance implications
Energy	• Accelerated deployment of renewable energy sources	• Geopolitical dependencies on critical materials for	• Low-income households • Renters • Older adults	• Community energy schemes to extend benefits

	• Smart grid expansion and advanced storage systems • Digital platforms enabling participatory energy models • EU and national decarbonisation targets (Fit for 55)	batteries and solar • Grid fragility and exposure to extreme weather events • Rising energy prices excluding low-income households from the transition • Benefits concentrated among property owners	• Digitally excluded individuals • Fossil-fuel workers • Small energy producers	beyond ownership • Targeted subsidies accessible without administrative burden • Anticipatory reskilling for fossil-fuel workers • Strategic material diversification to reduce geopolitical exposure
Transport and mobility	• Electrification of vehicle fleets and charging infrastructure rollout • Digital mobility platforms and interoperable transport services • EU sustainable mobility strategy and national EV targets • Business model innovation (mobility-as-a-service)	• Labour displacement in automotive and logistics sectors due to automation • Charging infrastructure gaps in rural and peripheral areas • High upfront cost of EVs limiting access for low-income users • Digital transport services inaccessible to digitally excluded groups	• Low-income households • Rural residents • Automotive & logistics workers • Digitally excluded users • People with disabilities	• Integrated rural mobility solutions to prevent transport poverty • Sectoral reskilling programmes tied to EV supply chain demand • Interoperability standards to enable seamless multimodal services • Inclusive design requirements for digital transport interfaces
Agriculture and food	• Digitalisation of agriculture (precision tools, AI irrigation, traceability) • CAP strategic plans promoting sustainable land management • Cooperative models scaling	• Digital and financial barriers excluding small-scale and older farmers • Automation displacing seasonal and low-skilled agricultural workers	• Small-scale farmers • Older farmers • Seasonal agricultural workers • Producers outside support networks	• Cooperative governance arrangements as entry-point for digital adoption • Proportionate regulatory compliance for small farms • Targeted advisory

	digital tools for smaller producers • Circular economy mechanisms reducing input dependency	• Unequal access to advisory systems and innovation networks • Regulatory compliance burdens disproportionate for small farms		services for digitally excluded producers • Social protection for seasonal workers facing automation-driven displacement
Housing and built environment	• Climate adaptation of housing stock and deep renovation strategies • Digital design and building management systems • EU energy performance of buildings directive and national renovation plans • Universal accessibility standards integration	• Renovation-driven displacement of low- and middle-income tenants • Uneven municipal capacity to access and deploy renovation funding • Digital-by-default service provision excluding residents without digital skills • Climate exposure concentrated in socially vulnerable neighbourhoods	• Low-income households • Renters • Residents in climate-exposed areas • Digitally excluded individuals • Low-skilled construction workers	• Capacity-building for municipalities with limited institutional resources • Affordability guarantees linked to energy performance improvements • Training pathways for construction workers aligned with new build requirements

Classification of statements >75% delphi survey

Table 4. Classification of statements (Source: Armayones Carranza & Viñé, 2025b)

Positive statements (>75% consensus)	Negative statements (>75% consensus)
Housing and built environemnt	
By 2050, the construction sector will be dominated by assembly and automation roles	Access to climate-adapted housing will be strongly stratified by income, with wealthier households better protected from climate risks by 2050
Public tender processes will increasingly favor construction companies that demonstrate climate adaptive design strategies	By 2050, concrete will remain the dominant construction material

	Energy prices will significatively influence incentives for adopting sustainable housing solutions
Agriculture and food	
Cross-sector alliances (e.g., agriculture, clean energy or pharma) will drive innovation and accelerate digitalization in the agri-food sector	Small farms will be affected by rising compliance costs tied to environmental regulations and certification system
Cloud-based platforms will deliver end-to-end “farm-to-fork” traceability visible to consumers	Automation in farming will significantly reduce the number of manual crop workers by 2050, especially among seasonal and migrant labour
Irrigation networks will use remote sensing and AI to schedule watering autonomously	
By 2050, most family farms will join cooperatively governed data hubs	
By 2050, edge-computing nodes (e.g. 5G base stations) will cover nearly all cultivated land, enabling real-time AI on remote farms	
No farm under 10 ha will be able to adopt precision technologies without joining a formal support network of service providers or cooperatives	
EU and/or national agricultural digitalization schemes will include mandatory regional customization clauses to reflect local climate, soil and crop differences	
Energy	
The transition towards wind and solar energy will continue accelerating	EU energy dependency on third countries for critical materials (e.g., lithium, rare earths) will be a strategic vulnerability
The main factors that will lead the energy transition will be the increase of prices, geopolitical aspects and environmental concerns	Grid resilience will face new challenges as illustrated by the solar-related blackout in Spain
The energy labor market will experience an increase in demand for highly skilled jobs, such as engineers	
The R&D&I on battery recycling will be a decisive factor in EU energy independence by 2050	
New financial models will arise due to the energy market incentives created by private companies and their technification	

Energy systems will be increasingly integrated with digital platforms, demanding strong data governance to protect consumers right	
Mobility and transport	
Battery recycling and domestic production will become critical strategic sectors for EV autonomy by 2050	The automatization of the traditional automotive manufacturing jobs will impact blue-collar workers
New business models such as Mobilit-as-a-Service (MaaS) models will be a reality in 2050	By 2050, the long-haul road freight and aviation sectors will rely primarily on synthetic fuels and bio-derived alternatives, as battery technologies will remain unsuitable for those use cases
Battery reuse and recycling will enable circular business models in the automotive sector	
Pan-European reskilling programs will have retrained the combustion-engine workforce for roles in EV maintenance, smart mobility services, and battery recycling	
By 2050, Europe will have established a circular battery economy in which end-of-life batteries are systematically reclaimed and processed through urban-mining and recycling facilities	

Complete scenarios (detailed). (Source: Armayones Carranza & Viñé, 2025a)

HOUSING AND BUILT ENVIRONMENT

Optimistic scenario – Twin transition takes place in the housing and built environment sector by 2050

By 2050, Europe's built environment is a model of climate resilience and health. Cities and towns have been reshaped through decades of investment in deep renovation and human-centered urban planning based on sustainable design. The housing stock is unrecognisable from the early 21st century; inefficient buildings have been replaced or retrofitted into spaces that are comfortable year-round, regardless of the climate hazards.

All homes meet or exceed the highest performance standards for insulation and ventilation, Natural light is maximised through intelligent design, and passive heating and cooling systems maintain comfort without mechanical strain. Materials are locally sourced, and chosen for their circular life cycle, so that components can be reused or recycled without waste. In apartment complexes, green roofs and living walls are the norm, improving biodiversity and urban air quality while regulating building temperatures.

Rainwater harvesting and greywater recycling are integrated into every building, reducing demand on municipal supplies and improving resilience.

Urban form has shifted toward mixed-use, walkable districts that integrate housing, services, and leisure spaces. Streets are shaded with trees and permeable pavements, cooling cities and preventing flooding during heavy rains. Public squares double as community gathering places and stormwater retention areas, designed to be both beautiful and functional. Parks and green corridors connect neighbourhoods, creating habitats for wildlife and safe spaces for people to meet and walk (or cycle).

Accessibility is universal. Homes and public buildings are barrier free, with wide corridors and adaptable interiors that can be easily modified to suit changing mobility needs. Wayfinding systems use clear signage to assist people with visual or cognitive impairments. For older adults and people with disabilities, assistive technologies are integrated into living spaces, from voice-controlled lighting and ventilation to fall- detection systems and responsive home layouts.

Affordability has been protected through long-term housing policy. Renovation subsidies and Inclusionary Zoning (IZ) ensure that low- and middle-income households benefit from transformation, avoiding the displacement that once accompanied urban renewal. In rural areas, buildings that were not used have been repurposed into modern housing clusters that support community life and provide access to essential services without long travel distances. Formerly neglected districts have been revitalised with high-quality, climate-adapted housing alongside cultural and commercial spaces that sustain local economies.

Neutral scenario – Partial achievement of the twin transition, coexistence of the new and the old (2050)

By 2050, Europe's built environment has been substantial improvements, yet its transformation remains uneven. Many cities have well-renovated housing and climate-resilient public spaces, but the depth and quality of these changes vary widely between regions. In leading areas, older building stock has been retrofitted to high performance standards (insulated façades, airtight windows, advanced ventilation systems...) which create comfortable interiors with reduced environmental impact. In other parts of the continent, however, renovations have been partial or delayed, leaving some homes still vulnerable to extreme weather and high maintenance costs. Material choices have been central to the divergence. In forward-moving regions, procurement policies have favoured local sourcing and recycling content, creating circular supply chains that keep carbon low. In other areas, budget constraints have led to retrofits with mixed-quality materials, some of which have limited life spans or higher environmental impacts, which will be translated into future maintenance costs-

Urban areas have embraced a mixed pattern of redevelopment. City centers often feature attractive, walkable districts with integrated green infrastructure. Yet in less well-funded municipalities, urban heat islands persist, and public realm improvements remain modest. Access to high-quality housing is also inconsistent: in thriving regions, affordability policies and inclusive zoning have kept costs stable, but elsewhere, gentrification and limited supply have pushed low- and middle-income residents to peripheral areas with fewer services.

Rural settlements have benefitted in pockets from adaptive reuse of old buildings and the creation of compact housing clusters close to essential services. In some areas, underused administrative buildings have been converted into modern community spaces, revitalising small towns. In other rural zones, however, depopulation has left housing stock deteriorating, with insufficient investment to reverse decline.

Accessibility has advanced, but progress is uneven. In well-resourced districts, barrier-free design is standard: step-free entrances, adaptable interiors, tactile signage, and smart navigation aids serve people of all ages and abilities. Elsewhere, retrofitting for accessibility has been slow, particularly in older buildings with structural constraints and funding gaps have delayed upgrades. Public spaces show similar disparities. Many metropolitan areas have created shaded pedestrian corridors and neighborhood squares that host markets and events, strengthening social cohesion. But in some towns and city outskirts, public spaces remain fragmented, lacking safe walkways or spaces for community gathering.

Pessimistic scenario – Negative trends and landscape shocks (2050)

By 2050, Europe's housing and built environment reflect decades of fragmented policy and insufficient investment, accompanied by escalating climate pressures. While some projects stand as symbol of ambition, they are exceptions in a place where much of the building stock remains outdated and inefficient. The renovation wave of the early 21st century stalled midway, leaving millions of homes with poor insulation and obsolete ventilation systems. Extreme heat in summer and cold snaps in winter make these homes uncomfortable and expensive to maintain, putting pressure on household finances and public health systems.

Material choices have been driven more by short-term cost-cutting than by sustainability or resilience. In many areas, low-grade imports have replaced durable and low-carbon options, leading to rapid deterioration and a cycle of constant repair. The absence of coherent circular-economy policies means demolition waste continues to pile up, while valuable materials are discarded instead of reused. Some urban districts have become patchworks of crumbling façades and mismatched retrofits, undermining both visual cohesion and community pride.

Urban planning has failed to keep pace with climate risks. Many city centers still rely on impermeable pavements and poorly shaded streets, making them hotspots for both flooding and heat stress. In wealthier areas, residents have invested privately in innovations such as cooling technologies and rooftop gardens; elsewhere, the lack of adaptation has left entire neighbourhoods prone to repeated climate-related damage. Public spaces in underfunded municipalities are scarce or degraded, with broken pavements or poorly maintained parks.

Accessibility remains inconsistent. While some newer developments include barrier-free entrances and adaptable interiors, many older housing remain inaccessible to people with reduced mobility. Lack of lifts and narrow staircases, as well as absence of visual aids, limit participation in community life for older adults, disabled people and parents with small children. Rural areas face additional challenges, as depopulation has left housing stock to decay, and limited resources mean essential accessibility upgrades are rare.

Affordability has worsened in many urban centers. Housing shortages, combined with speculative investment in prime locations, have driven up rents and prices, pushing low- and middle-income residents to peripheral areas with limited infrastructure and poor-quality housing. Informal settlements have emerged in areas around cities in some regions, where residents occupy unfinished or abandoned buildings with minimal services.

AGRICULTURE AND FOOD

Optimistic scenario – Twin transition takes place in the agriculture and food sector by 2050

By 2050, Europe's agricultural sector embraced both sustainability and digitalisation, creating a system that is productive, resilient, and fair. Farms of all sizes use advanced tools to manage resources efficiently and meet high environmental standards. Cross-sector alliances between agriculture, clean energy, and technology have become common, pooling expertise and funding to deliver solutions that were once out of reach for smaller producers. These partnerships have driven the spread of innovations such as bioenergy-powered greenhouses, solar-powered irrigation, and digital tools for monitoring soil health.

Cloud-based traceability platforms now connect farms directly to consumers, making it possible for shoppers to see where their food comes from, how it was produced, and its environmental footprint. This transparency has built trust and opened new markets for farmers who meet high sustainability criteria, including premium prices for certified products. Smaller farms benefit by differentiating their produce and reaching customers willing to pay for quality and accountability.

Water use has become far more efficient thanks to irrigation networks guided by remote sensing and AI. Satellites, IoT sensors, and weather forecasts feed into autonomous systems that deliver water only when and where it is needed. This has cut costs, reduced waste, and helped farming adapt to more frequent droughts. Even in traditionally dry areas, crop yields are stable, and farmers are less dependent on expensive emergency water supplies.

Family farms thrive within cooperatively governed data hubs, which act as shared knowledge centers and service providers. These hubs give members access to AI-driven crop models, carbon market participation, and affordable insurance. The cooperative structure ensures that decisions are made locally and benefits are shared fairly. Small farms, once at risk of falling behind, have equal access to the same cutting-edge tools as larger operations.

Edge-computing coverage now extends to almost every field, enabling real-time AI for farm management. Autonomous tractors, drones, and robotics operate with precision, reducing input costs and improving productivity. Even the smallest farms can use precision technologies by joining formal support networks or cooperatives, which provide shared access to machinery, training, and maintenance. This arrangement has kept technology adoption high while preventing smaller producers from being left behind.

Policies now require agricultural digitalisation schemes to be tailored to local conditions, recognising that a vineyard in southern Spain has different needs from a dairy farm in northern Germany. This regional customisation has made digital tools more relevant, increasing their adoption and impact. Advisory services are staffed with local experts who understand the specific climate, soil, and crop challenges of each region.

For disadvantaged subgroups, the changes have been tangible. Low-income rural households have stable incomes through cooperative membership and access to premium markets. Migrants are employed in skilled roles operating and maintaining advanced agricultural systems, supported by training in both technology and language. Older farmers have remained active by working within cooperatives that handle the most complex digital tasks, while providing them with tools they can use confidently. People with disabilities find more accessible employment opportunities in roles involving monitoring, data analysis, and cooperative management. Rural communities once left behind now enjoy better infrastructure, stronger local economies, and improved food security.

Agriculture in 2050 is no longer divided between the winners and losers of change. Instead, it is a connected, adaptive system where sustainability and technology work together, and where even those in remote or small-scale settings share in the benefits of the twin transition.

Neutral scenario – Partial achievement of the twin transition, coexistence of the new and the old (2050)

By 2050, Europe's agricultural landscape shows progress toward sustainability and digitalisation, but the picture is uneven. Many farms have adopted advanced tools and more sustainable practices, while others continue with older methods, creating a patchwork of progress. Cross-sector alliances between agriculture, clean energy, and technology exist but are concentrated in certain regions and sectors. In areas with strong investment and political support, these partnerships have brought more efficient production and innovative practices. In other regions, limited funding and fragmented networks have slowed change.

Cloud-based traceability systems are widely used by large and export-oriented farms, helping them reach premium markets with detailed information on product origin and sustainability. However, smaller farms without the resources or capacity to meet certification standards often operate outside these platforms, selling into local markets where traceability is less valued. The gap between farmers able to benefit from consumer demand for transparency and those left in traditional supply chains has not been fully closed.

Irrigation networks that use AI and remote sensing operate in many regions, especially those prone to drought, but not everywhere. Some farmers still rely on conventional systems, either because of cost barriers or limited access to the infrastructure needed. As a result, water efficiency has improved overall, but unevenly, and some areas still face stress during prolonged dry spells.

Family farms participate in cooperatively governed data hubs in several Member States, gaining access to shared tools and services. Yet membership is far from universal, and many small farms remain outside these structures, either due to mistrust, lack of awareness, or reluctance to share data. Where hubs function well, they improve competitiveness and sustainability. Where they do not exist or are poorly managed, farms struggle to keep pace with technological change.

Edge-computing coverage enables real-time AI in many agricultural areas, but there are still gaps in remote and mountainous regions. Farmers in well-connected areas use autonomous equipment and data-driven decision-making, while those in poorly served zones rely on less precise methods, creating disparities in productivity and efficiency.

Policies for regional customisation of digitalisation schemes are in place, but their implementation varies. In some countries, adaptation to local climate and soil conditions have made tools more relevant and effective. In others, generic approaches have reduced their usefulness, leading to low adoption.

The impact on disadvantaged subgroups is mixed. Low-income rural households in regions with strong cooperative structures benefit from stable income and better market access, while those in less connected areas see fewer gains. Migrants continue to work in agriculture, but many remain in seasonal manual roles because training for higher-skilled positions is uneven. Older farmers adapt better in areas where cooperatives provide technical support, but in less organised regions they face challenges in meeting new requirements. People with disabilities have more opportunities on some modernised farms, but accessibility is still inconsistent.

In this 2050, agriculture reflects both the achievements and the missed opportunities of the twin transition. Progress is visible, but uneven adoption, infrastructure gaps, and persistent inequalities prevent the sector from fully realising its potential for inclusivity and sustainability.

Pessimistic scenario – Negative trends and landscape shocks (2050)

By 2050, Europe's agricultural sector is struggling to adapt to the demands of sustainability and digitalisation. Progress has been uneven and, in many places, slow. Small farms face rising compliance costs tied to environmental regulations and certification systems. For many, meeting the requirements for eco- schemes, carbon reporting, and traceability is financially and administratively overwhelming. Larger farms, with dedicated staff and greater resources, absorb the changes with less difficulty, widening the gap between big and small producers. Some smallholdings have closed, while others have been absorbed by bigger operations, leading to reduced diversity in rural systems and the erosion of traditional farming knowledge.

Automation in farming has advanced rapidly, replacing a large proportion of manual crop work, especially among seasonal and migrant labour. While this has improved efficiency, it has also displaced many low- skilled workers. In regions that once depended on seasonal agriculture for employment, job losses have driven migration, economic decline, and social strain. Few retraining programs have been implemented, and those that exist are often mismatched to the local labour market.

Other positive developments that could have bridged the gap have failed to reach their potential. Cross-sector alliances remain small in scale and are mostly limited to high-tech farms. Cloud-based traceability systems exist but are inaccessible to many smallholders who lack the funds or digital infrastructure to join them. Irrigation systems using AI and remote sensing operate mainly in wealthy regions, leaving others vulnerable to worsening droughts. Cooperatively governed data hubs function in pockets of Europe, but in many areas, they have not been established or have collapsed due to lack of trust and funding.

Edge-computing coverage is far from universal. In many rural and mountainous areas, connectivity remains poor, preventing farmers from using autonomous machinery or real-time decision-making tools. This leaves them less productive and less competitive in increasingly globalised markets. Policies requiring regional customisation of digitalisation schemes have been poorly implemented, leading to tools that do not reflect local climate and crop needs, further discouraging adoption.

The consequences for disadvantaged subgroups are severe. Low-income rural households face shrinking income opportunities and higher production costs, pushing many out of farming entirely. Migrants, once a significant part of the agricultural workforce, have been displaced by automation without access to new employment pathways. Older farmers are disproportionately affected by digitalisation requirements, with many unable to adapt and therefore excluded from subsidy schemes. People with disabilities and those in remote areas find even fewer opportunities in agriculture, as most accessible roles are concentrated in regions with advanced infrastructure.

The sector's vulnerability to climate change has worsened. Without widespread adoption of smart irrigation or precision agriculture, yields fluctuate with extreme weather. Droughts, floods, and heatwaves regularly disrupt production, reducing food security and increasing dependence on imports. Rural depopulation accelerates as young people leave for better prospects elsewhere, leaving behind ageing communities with limited capacity to maintain agricultural output.

In this 2050, the twin transition in agriculture has faltered. The promise of technology and sustainability has been realised only in isolated pockets, while large parts of the sector remain trapped in a cycle of high costs, low productivity, and exclusion. Inequalities have deepened, and the gap between the best-equipped farms and those left behind has become a defining feature of the rural landscape.

ENERGY

Optimistic scenario – Twin transition takes place in the energy sector by 2050

By 2050, Europe's energy system is almost entirely powered by wind and solar. Offshore wind farms stretch along the coasts, producing large amounts of electricity. Solar panels cover rooftops, building walls, parking areas and farmland, often combined with crops in agrivoltaic systems. These renewable sources meet nearly all electricity demand across the continent. The challenges that once came with such high levels of renewables, like unstable voltage, low grid inertia or risk of blackouts, have been solved. Large-scale batteries, green hydrogen storage and smart grid technology keep the system stable. Automatic controls and real-time monitoring mean the grid can adapt before problems appear, even during extreme weather.

The shift to this system began decades ago. Rising fossil fuel prices made renewable energy more attractive. Political tensions over energy imports showed how risky dependency could be. People have become more aware of the need to protect the environment, pushing governments to act. Rules that used to delay renewable projects were changed, making it easier and faster to build. Clear plans were set to reduce and then stop the use of fossil fuels. The cost of renewable technology has dropped steadily, helping more people and businesses to invest.

Digital platforms are now a normal part of daily life. Every household and business can check where their energy comes from, how much they are using and how much it costs. Many store extra power in batteries and sell it back to the grid at times of high demand, earning extra income. These platforms are easy to use, and strict rules protect people's personal data. Because of this, trust in the system is high.

One of the biggest changes has been in battery recycling. Batteries are now made to be repaired, reused or taken apart so that their materials can be recovered. This has reduced Europe's need to import lithium, rare earths and other critical materials. Large recycling centers have opened in towns that once depended on coal mines or heavy industry. These centers provide good jobs for former fossil-fuel workers, newly trained technicians and young graduates in engineering and manufacturing.

The benefits are shared widely. Low-income households live in well-insulated and energy-efficient homes. Many have their own solar panels or are part of community-owned energy projects that lower their bills and sometimes pay them a share of the profits. Rural communities run local wind farms and storage systems, using the income to improve services like schools, healthcare and internet access. People who rent their homes, once excluded from most of these benefits, now join through shared ownership programs, virtual net metering or subscription-based clean energy plans.

In this future, the system is designed for inclusion. Migrants and people who do not speak the local language well can access training and support to find jobs in the energy sector. Older people and those with disabilities use simple displays, voice controls or other adapted tools to manage their energy use. Energy and digital skills are taught in schools and offered to adults, making it possible for everyone to take part.

Europe in 2050 reached its climate goals and built an energy system that is clean, reliable and fair. Electricity is affordable for all, jobs are secure and spread across regions, and communities have more control over their energy future. The twin transition has brought environmental protection and social fairness together, showing that both can be achieved at the same time.

Neutral scenario – Partial achievement of the twin transition, coexistence of the new and the old (2050)

In 2050, Europe's energy landscape shows clear progress, but the transformation is uneven. Renewable energy from wind and solar provides a significant share of electricity, and in some regions it is the dominant source. Offshore wind farms operate efficiently along many coasts, and solar panels cover public buildings, homes, and farmland. Yet, fossil fuels still play an important role in the system. Gas plants are kept as backup for periods of high demand or low renewable generation, and some coal facilities remain active in countries that have struggled to replace them.

The advances that have made high renewable penetration possible are present, but not everywhere. In well-connected areas, large-scale batteries, hydrogen storage, and advanced control systems keep the grid stable. Elsewhere, infrastructure is older and less flexible, making it harder to manage fluctuations. Extreme weather events sometimes lead to temporary supply interruptions in these regions, reminding people that reliability is still uneven.

Digital tools have changed how many households and businesses interact with the energy system. In urban centers and connected rural areas, people monitor their energy use in real time, store extra power, and sell it back to the grid when prices are high. In these places, dynamic pricing schemes and automated systems help balance supply and demand. However, participation is not universal. Rural residents in areas with weak internet connections, older adults unfamiliar with digital platforms, and migrants facing language barriers often cannot use these services fully.

Battery recycling has improved and now provides a steady supply of materials like lithium and rare earth, reducing but not removing Europe's reliance on imports. Disruptions in supply still occur, and when they do, they can slow down new renewable projects and raise costs. Employment patterns also vary. Regions that embraced renewables early enjoy strong job markets in engineering, maintenance, and manufacturing. Other areas, particularly those that were slower to attract investment, continue to see higher unemployment and limited opportunities for workers from traditional energy sectors.

For specific groups, the picture is mixed. Low-income households in proactive municipalities benefit from energy-efficient homes, solar access, and stable bills. In less engaged regions, they face higher costs and fewer support programs. Renters gain access to shared solar projects and virtual net metering in some areas, but elsewhere their landlords have not invested in energy improvements, leaving them with high bills. Rural communities in connected zones run profitable local projects and reinvest in public services, while others without such infrastructure miss out on these gains. Migrants in some regions find training and jobs in the energy sector, while in others they remain excluded by language and recognition barriers. Former fossil-fuel workers have transitioned successfully where retraining programs are linked to local jobs, but many in slower-moving regions work in lower-paid or insecure jobs.

This Europe has made important steps toward a clean and modern energy system, but progress is uneven. Renewables and digitalisation have improved efficiency and reduced emissions, yet fossil fuels still fill important gaps. The benefits of the transition are visible, but they do not reach all communities equally, leaving parts of society still waiting for the full promise of the twin transition.

Pessimistic scenario – Negative trends and landscape shocks (2050)

In 2050, Europe's energy system is under strain. The shift to renewables has slowed, and fossil fuels remain a large part of the mix. Some wind and solar projects have expanded, but their growth has been held back by delays in infrastructure, supply chain disruptions, and political disagreements over funding. Several countries still rely heavily on gas and coal to meet demand, especially during winter peaks. The result is a system that is less clean, less reliable, and more vulnerable to external shocks.

Import dependency on critical materials like lithium and rare earths remains high. Global tensions and export restrictions have led to repeated shortages, delaying battery production and renewable deployment. Costs have risen, making new projects harder to finance. Instead of achieving energy independence, Europe faces regular supply disruptions that force governments to restart or extend the life of fossil-fuel plants. These decisions are framed as necessary for stability, but they keep emissions high and slow the move toward climate goals.

Digitalisation has advanced unevenly. Some urban areas have smart grids and automated energy management, but much of the system still relies on outdated infrastructure. Large parts of the population cannot participate in dynamic pricing schemes or benefit from grid-connected storage. The lack of strong data governance in some countries has also led to privacy concerns and public mistrust, reducing the uptake of digital energy services.

The job market shows deep divides. High-skilled positions in advanced renewable technology are concentrated in a few economic hubs, while many regions have seen job losses from the closure of fossil- fuel industries without equivalent opportunities to replace them. Retraining programs have been patchy and often poorly matched to the needs of local economies. Former fossil fuel workers in these areas face long-term unemployment or accept lower-paid, insecure jobs.

The social impact of these failures is significant. Low-income households face higher and more unstable energy bills, as subsidies are inconsistent and fossil fuel prices fluctuate. Rural communities in less developed regions have limited access to renewable projects and remain dependent on expensive imported fuels. Renters are often left behind because landlords have not invested in energy efficiency or clean energy, keeping their bills high. Migrants and people with limited language skills face additional barriers to joining the energy workforce or accessing support programs. Older adults and people with disabilities struggle with poorly designed interfaces and a lack of tailored assistance, leaving them excluded from digital services that could reduce their costs.

Frequent extreme weather events have exposed the fragility of the system. Heatwaves, storms, and floods have caused repeated power outages in vulnerable areas. Without adequate investment in grid resilience, recovery from these events is slow, deepening inequalities between well-prepared regions and those left without resources.

This is a Europe where the twin transition has not delivered its promise. Renewable deployment has stalled, fossil fuel dependence persists, and the benefits of technology are concentrated in a few places. Many communities are locked in cycles of high costs, limited job opportunities, and vulnerability to climate impacts. The gap between those who can participate in and profit from the energy system and those who cannot has widened, turning the energy transition into a source of division rather than a driver of unity.

MOBILITY AND TRANSPORT

Optimistic scenario – Twin transition takes place in the mobility and transport sector by 2050

By 2050, Europe's mobility system is an integrated, low-emission network that is both inclusive and sustainable. Electrification dominates urban and intercity travel, supported by diverse technologies that reflect strategic decisions made decades earlier. Electric vehicles account for nearly all private car sales, but the shift is not limited to ownership: subscription-based "car as a service" models and well-established Mobility-as-a-Service platforms allow access to shared, on-demand fleets in every major city. These platforms integrate booking and payment, as well as routing, across trains, buses, shared EVs, micromobility, and demand-responsive shuttles, replacing much of the friction once found between modes. While private cars still exist, they are fewer and cleaner, and they are integrated in a system optimised for connectivity and efficiency.

Urban and rural transport fleets are fully electric, reducing both noise and air pollution. In non-urban areas, integrated rural mobility hubs have transformed access to work and education. These hubs combine shared electric vehicles, regular buses, on-demand mobility, and micromobility options. They are designed with universal accessibility in mind and have reduced transport poverty in areas that were once underserved.

Circular economy principles are characteristic of the automotive value chain. Domestic battery production, using diversified chemistries based on locally available materials, has reduced dependency on imported critical minerals. En-of-life batteries are reclaimed and processes through advanced recycling facilities, many located in towns that once depended on combustion-engine manufacturing. This has created stable jobs in battery recycling and second-life applications.

These shifts are supported by long-term investment in reskilling. Pan-European programs have retrained former blue-collar workers in EV maintenance, battery diagnostics, and smart-mobility service. Training is linked directly to hiring pipelines, ensuring that former fossil-fuel automotive workers and those from declining logistics subsectors move into stable employment without prolonged unemployment.

For low-income households, targeted subsidies and affordable leasing models remove upfront cost barriers. Shared EV schemes, supported by municipal and cooperative ownership, give them access to electric mobility without the cost of ownership. Rural communities benefit from the mobility hubs, with coordinated timetables reducing long travel times to jobs and services. Renters in dense urban areas, once excluded from EV incentives due to lack of private charging, gain from widespread charging in neighborhood-based shared fleets. Migrants and people with limited bureaucratic literacy are supported by one-stop mobility centers that provide multilingual assistance for subsidy applications and account set- up for MaaS platforms, reducing exclusions. Older adults enjoy barrier-free vehicles and priority, easy-to- use booking systems across fleets, while people with disabilities benefit from universal design standards included in every vehicle and hub.

Neutral scenario – Partial achievement of the twin transition, coexistence of the new and the old (2050)

In 2050, Europe's mobility landscape reflects both the successes and limits of the twin transition. Electrification and digitalisation have advanced substantially, but the pace and consistency of change vary widely depending on the market and geographical scope. Electric vehicles dominate new car sales in many urban areas, supported by robust charging networks and subscription-based "car as a service" models, but in smaller cities and rural zones, internal combustion vehicles (often running on hybrid or biofuel blends) remain common, coexisting with EVs. MaaS platforms are well-developed in major metropolitan regions, offering integrated booking for trains, buses, shared EVs, and micromobility. In other areas, fragmented ticketing systems and limited operator participation prevent full integration.

Public transport electrification is significant but incomplete. While most urban bus fleets are battery-powered and quiet, some interurban roues and regional lines still rely on diesel or LNG because of infrastructure and cost constraints. Rural mobility hubs exist in certain countries, but their coverage is uneven. In underserved regions, car dependence remains high, reinforcing disparities in access to services and jobs.

Battery recycling and domestic production have grown, but dependence on imported materials persists. Circular-economy initiatives recover a portion of lithium, cobalt, and nickel from end-of-life batteries yet processing capacity is concentrated in a few industrial clusters. This creates regional imbalances in job creation, with some former automotive-manufacturing areas thriving while others face prolonged adjustment periods. Reskilling programmes have reached any, but participation rates are uneven, and training does not always match local job demand, leading to some workers accepting lower-paid roles in unrelated sectors.

For low-income households, targeted subsidies and affordable leasing exist in some member states, but eligibility criteria and application complexity, as well as budget limits, keep adoption rates modest. Many remain dependent on older, less efficient vehicles, exposing them to higher operating costs. Rural communities benefit when mobility hubs are funded, yet in many places public transport remains infrequent, forcing continued reliance on private cars. Renters without private parking see improved access to chargers in cities with strong policy frameworks, but in less regulated markes, charging availability lags EV growth. Migrants and people with limited bureaucratic literacy gain mobility when local authorities provide support for MaaS apps and subsidy applications, but in many regions such assistance is ad hoc or NGO-led. Older adults experience greater comfort and accessibility on modernised fleets where investment has been made, yet in other areas booking systems remain barriers. People with disabilities are well-served In flagship MaaS neworks and urban transport upgrades, but universal design standards are inconsistently enforced outside major cities. They can access mobility systems through physical ticket offices and phone booking in some systems, but in many cases digital-only platforms create silent exclusion.

Pessimistic scenario – Negative trends and landscape shocks (2050)

By 2050, the promise of an inclusive and sustainable mobility transition has not been realised. Electrification has advanced in some wealthy urban sites, but large parts of Europe still rely on older combustion vehicles, often running on imported fossil fuels or low-grade biofuel blends. Fragmented regulation and insufficient investment have stalled the rollout of charging infrastructure, leaving many regions as "charging deserts". The absence of a coordinated approach has locked in a two-speed transition: metropolitan centers enjoy modern fleets and digital integration, while rural and peri-urban areas remain dependent on outdates, polluting vehicles.

MaaS platforms exist in name but fail to deliver integration. Private operators guard data, and public systems lack the capacity to enforce interoperatibility. As a result, passengers must juggle multiple apps and payment systems. Public transport electrification is incomplete; diesel buses and ageing trains are still in service on many regional and rural routes. The few rural mobility hubs that were launched early in the transition have closed due to underfunding, and worsening transport poverty for low-density communities.

Battery production remains heavily dependent on imported critical minerals, making the sector vulnerable to price spikes and supply interruptions. Circular-economy goals for battery reuse and recycling were not met; most end-of-life batteries are processed abroad, losing both materials and job opportunities. Automation in vehicle manufacturing has accelerated without adequate reskilling programmes, leaving large numbers of former automotive and logistics workers unemployed or in precarious, low-paid jobs.

For low-income households, the high upfront cost of EVs remains prohibitive. Subsidies either no longer exists or are structured in ways that favour wealthier buyers who can afford initial payments and navigate complex applications. Operating older combustion cars exposes these households to volatile fuel prices and stricter emissions charges, deepening financial strain. Rural communities suffer from the collapse of mobility hubs and long gaps in public transport coverage, forcing continued dependence on expensive private vehicles. Renters without private parking face near-total exclusion from EV ownership, with charging spots limited to wealthier districts. Migrants and those with limited bureaucratic literacy are disproportionately excluded from incentives and subsidies, as assistance services have been cut. Older adults can't use digital booking and payments systems that have replaced physical ticketing, and can’t use MaaS services, which have shifted to digital-only formats as well, cutting them off from modern mobility options. People with disabilities face inconsistent or absent accessibility features in vehicles and stations.