Skill Resilience 4EU

SkillResilience4EU
Resilience through re-skilling and upskilling for European labour markets in transition

D4.2 – Identification of patterns of institutional dynamics related to the twin transition and their drivers and case study reports

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Abbreviations and acronyms

Abbreviation or acronym used in this document	Explanation
BOKU	BOKU University
CCS	Carbon Capture and Storage
COVID-19	Coronavirus pandemic
DMO	Destination Marketing Organization
EU	European Union
FHNW	University of Applied Sciences and Arts Northwestern Switzerland
HEI	Higher Education Institution

HVL	Western Norway University of Applied Sciences
LSE	London School of Economics
NGO	Non-governmental Organization
NUTS	Nomenclature of Territorial Units for Statistics
UoC	University of Crete
UU	University of Utrecht
UW	University of Warsaw
VET	Vocational Education and Training
WP	Work Package

Glossary

Term	Definition used or meaning in the Acronym project	Reference or source for the definition if applicable
Agency	Purposeful actions of individuals or organizations within institutional contexts, including efforts to create, maintain, or transform institutions.	Emirbayer & Mische, 1998
Events	Discrete occurrences marking meaningful organizational or institutional changes; used as empirical indicators.	Langley, 1999; Strambach & Pflitsch, 2020
Institutions	Shared rules, norms, and expectations guiding behaviour beyond individual actors, including regulative, normative, and cognitive elements.	Scott, 2001
Multi-scalar process	Processes unfolding across multiple spatial or governance levels, with interactions and feedback between scales.	Miörner & Binz, 2021
Organisations	Configurations of institutional structures and practices; both shaped by and shaping institutions.	Greenwood & Suddaby, 2006
Process approach	Methodological approach focusing on emergent, evolving phenomena and their interactions over time.	Langley, 1999
Topology visualizer	R-based open-source application that generates transition topology maps from structured case data, allowing users to create, filter, and export visualizations without programming skills.	
Transition	Visual maps (directed graphs) that allow the	Strambach & Pflitsch,

topology	structured analysis of key institutional and organizational changes in a transition process, including their temporal sequencing.	2020

Executive Summary

Deliverable 4.2 (D4.2) presents the methodology and findings of Task 4.2, which are based on an in-depth analysis of the micro-dynamics underlying the institutional and organisational changes mapped in the established transition topologies in D4.1. Building on the 13 case studies across five sectors (tourism, food, transportation, energy including cybersecurity and emerging sectors, and agriculture), Task 4.2 examines how regional actors respond to changes in national and international institutional environments and broader macro-level drivers, or even proactively drive change with regard to the green and digital transition at the regional level. This deliverable thereby provides the analytical foundation for the focus groups as well as for identifying governance challenges and opportunities in subsequent tasks of WP4.

Conceptually, D4.2 builds directly on the neo-institutional framework established in D4.1, which focuses on the interplay of institutions, organisations, and agency in gradual institutional change across different scales. Methodologically, the analysis deepens the processual, embedded case study design of D4.1 shifting from data structuring to interpretative analysis. D4.2 focuses on the identification of patterns, the reconstruction of micro-dynamics underlying the events and activities captured in the transition topologies. The in-depth analysis is guided by two research questions derived from existing research, which are complemented by guiding questions. RQ1 examines the extent to which a twin transition can be observed at the regional level within the institutional context of the labour market, and what drivers and barriers shape these dynamics. RQ2 examines how skilling and reskilling initiatives evolve at the regional level in the context of the twin transition, and which drivers and barriers shape these processes. Building on these RQs, WP4 provided a structured workflow and templates that supported partners with analysing the micro-dynamics of institutional changes in their respective cases.

The findings across cases deepen the preliminary observations of D4.1. Regarding RQ1, the in-depth analysis shows that greening and digitalisation follow distinct temporal trajectories and logics. Greening processes tend to emerge earlier than changes linked to digitalisation in most cases. Greening dynamics follow different logics across cases, with some transition topologies characterized by predominantly top-down regulatory processes, while others are driven primarily by bottom-up, value-based greening initiatives. Efficiency-oriented logics also play an important role in greening processes within certain sub-sectors. In contrast, digitalisation is driven primarily by market- and efficiency-oriented considerations. Furthermore, the findings suggest that the twin transition does not emerge automatically from the parallel development of greening and digitalisation at the regional level. Although evidence of coupling remains scarce in some cases, the analysis identifies three mechanisms that facilitate integration between the two transitions: Coupling either emerged through proactive intermediary actors, through regulatory impulse or crisis-driven integration such as the Covid-19 pandemic. Barriers for the twin transition are identified with regards to SMEs and uncoordinated translation of macro-level events and policies into regional institutional settings.

With regard to RQ2, the in-depth analysis reveals that skilling initiatives followed rather than preceded or ran parallel to the broader transition dynamics across the majority of cases. Similar to the findings of RQ1, greening-related and digitalisation-related skilling initiatives emerged through fundamentally different institutional logics and actor constellations. Integrated twin transition skilling remains rare across all cases. Existing barriers include the different actor groups and logics driving initiatives with regards to green and digital skills, delayed public institutional responses toward skill demand, misalignment between multi-level dynamics as well as structural barriers for SMEs. Explicit re- and upskilling is only evident in a few cases.

Together, the findings of D4.2 provide the analytical basis for the focus group activities in D4.3 which will present these findings back to regional actors for validation and discussing identified governance challenges and opportunities. They further provide the foundation for the comparative analysis of regional institutional transition pathways across sectors and regions which will provide recommendations for institutional transitions of the labour market in D4.4.

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1. Introduction

1.1 Purpose of the document

WP4 focuses on the analysis of the institutional context for labour market resilience in the regional case studies of the SkillResilience4EU project. Task 4.2 concentrates on the in-depth analysis of the micro-dynamics underlying the institutional transformations visualized in D4.1's transition topologies. It further shows how national/international institutional environments and macro-drivers shaped these regional dynamics over time. The purpose of this deliverable (D4.2) is to document and present the methodology developed and applied in Task 4.2 of WP4, "In-depth analysis of institutional dynamics" and present the findings from all case studies, in form of detailed case study reports.

Task 4.2 has been led by BOKU with contributions from HVL, FHNW, LSE, UoC, UU and UW. Deliverable 4.2 builds on the initial findings from the project's case studies (D4.1), for which data has been collected in collaboration with WP3 (Task 3.1). In D4.1, these findings consist of the transition topologies and the corresponding descriptive case narratives, for the 13 case studies in five sectors (tourism, food, transportation, energy including cybersecurity and emerging sectors, and agriculture). The in-depth analysis of the transition topologies (D4.2) provides a foundation for subsequent tasks within WP4.

1.2 Intended readership

The deliverable is directed to a range of audiences. Policymakers at different levels may utilise the report to understand the impact of the twin transition on labour markets and their institutional context. In particular, regional and national decision-makers who are engaged with the institutional and organizational contexts of regional labour markets examined in the case studies may be interested in the results presented. In addition, education and VET providers might find valuable insights into how the twin transition shapes the regional institutional context of labour markets and how actors respond to this. Beyond this, it may be relevant to scholars in economic geography, public policy and governance, labour market/VET studies and related fields.

1.3 Structure of the document

The document is structured as follows. Chapter 2 contextualises Task 4.2 within the work package and the overall project. In addition, Chapter 2 provides a summary of the conceptual and methodological approach, which has been described in detail in Deliverable 4.1. It furthermore outlines the research design as well as the preparatory and implementation steps for the in-depth analysis of the 13 regional case studies. Chapter 3 then presents the findings from the in-depth analysis, examining the micro-dynamics underlying the institutional transformations visualised in D4.1's transition topologies and highlighting how national and international institutional environments, and particular macro-drivers, have shaped regional dynamics over time. Chapter 4 concludes the document and outlines the next steps in WP4.

1.4 Relationship with other deliverables

This deliverable builds on the data collected in cooperation with WP3. In particular, it includes inputs from Task 3.1, i.e., the data collection and preparatory desk research underpinning the project's case studies. It directly builds on the transition topologies developed in D4.1 and contributes to subsequent activities in WP5 and WP6, particularly those deliverables addressing

the analysis of policy frameworks and education programmes (D5.2 and D6.1). The conceptual insights on institutional dynamics for regional labour market resilience will furthermore feed back into the conceptual framework of WP1 (D1.4).

Within WP4, this deliverable provides the analytical foundation for the subsequent focus group activities in D4.3, which aim at identifying and discussing governance challenges and opportunities in the case studies with regional stakeholders. Together, D4.1 and D4.2 underpin the comparative analysis of regional institutional transition pathways across sectors and regions in D4.4.

2. Methodology and methods

After describing the role of Task 4.2 within the overall project, this chapter briefly summarises the conceptual foundations and methodological approach, which have been presented in detail in D4.1. Building on this, the chapter derives two key research questions that guide the analysis in D4.2. Afterwards, it elaborates in detail how the analysis was structured and conducted in line with these questions and across the 13 cases. This section furthermore includes a brief recap of the research design developed in D4.1. Together, these elements establish the conceptual and procedural basis for the in-depth analysis of the transition topologies presented in Chapter 3.

a. Task objectives and contribution of D4.2

The overall aim of the SkillResilience4EU project is to support inclusive and sustainable transitions of regional economies and labour markets under the twin transition. The overarching goal is thus to ensure that regions and actors can adapt to change induced by the twin transition while minimizing risks of social exclusion.

WP4 plays a central role within the overall SkillResilience4EU project by linking macro-level drivers of change, such as technological developments, policy frameworks, and broader institutional shifts, with micro-level processes of institutional adaptation and agency at the regional level. It thus investigates the institutional conditions that enable inclusive and sustainable transformations at the regional level. Moreover, it makes apparent how regional actors respond to, adapt to, or even actively shape institutional change in the context of broader macro-level dynamics.

In this sense, WP4 complements the macro-level quantitative analyses in WP1 and WP2 by providing a qualitative, process-oriented institutional perspective. In relation to WP3, which analyses labour market dynamics primarily at the firm level (e.g., changes in skills and competencies and organisational strategies), WP4 analyses these strategies within their broader multi-scalar institutional and organisational contexts. It furthermore complements WP5 and WP6 by examining the actual implementation and (long-term) impacts of policy frameworks and education programmes at the regional level.

Within WP4, Task 4.2 focuses on the micro-dynamics underlying the institutional transformations identified in D4.1's transition topologies. It examines how regional actors respond to changes in national and international institutional environments and broader macro-level drivers, or even proactively drive change regarding the green and digital transition at the regional level. It thereby provides the analytical basis for stakeholder engagement in Task 4.3 and for cross-case comparison in Task 4.4.

b. Conceptual and methodological foundations established in D4.1

This deliverable builds on the conceptual and methodological approach developed in D4.1, which conceptualises regional labour market resilience as a dynamic and evolutionary process. The latter is understood as fundamentally shaped by institutional change. Adopting a neo-institutional perspective, the approach focuses on how institutions both enable and constrain change within regional labour markets. It puts particular attention to the micro-dynamics of such processes.

The conceptual framework is based on three central elements that are seen as closely entangled: institutions, organisations, and agency. Institutions are understood as multi-dimensional

arrangements comprising regulative (e.g., laws, formal rules), normative (e.g., values, norms), and cognitive elements (beliefs, worldviews) that structure the behaviour of actors (Scott, 2001). Organisations are both influenced by but can also transform these institutional arrangements themselves (Greenwood & Suddaby, 2006; DiMaggio & Powell, 1983). Agency is defined as the purposive action of actors, whose practices (institutional work) drive processes of institutional stability and change (Emirbayer & Mische, 1998; Lawrence & Suddaby, 2006). These dynamics are conceptualised as inherently multi-scalar, i.e. as emerging from interactions across regional, national, and supranational levels (Miörner & Binz, 2021).

Methodologically, the research conducted in WP4 follows the approach of transition topology (Strambach & Pflitsch, 2020). The latter applies a process-based perspective (Langley, 1999), focusing on the reconstruction of institutional change over time. Events of organisational and institutional change serve as observable proxies for on-going institutional change and its underlying micro-dynamics. The approach combines a narrative analysis with a visual mapping to systematically analyse how institutions, organisations, and agency co-evolve across time and space. This process-based approach is applied within an embedded case study design, which allows to capture regional processes of institutional change as influenced by processes on other spatial scales. In this way, it provides the foundation for the in-depth analysis conducted in D4.2.

c. Research questions guiding the analysis in D4.2

Building on the objective of WP4 and the overall project goals, the in-depth analysis of the case studies in Task 4.2 is guided by two core research questions. These questions define the focus of the analysis in this Task by addressing the key dimensions of institutional change relevant to the resilience of regional labour markets under the “twin transition” and associated macro-level trends.

The research questions draw on the conceptual framework developed in D1.4, which understands labour market resilience as the outcome of interactions between macro- and micro-level drivers and their combined effects on skills mismatches and labour market exclusion. They are furthermore anchored in the conceptual foundations elaborated in D4.1, particularly in the neo-institutional, process-oriented approach described above. Both research questions thus examine changes in the institutional and organisational context of regional labour markets, covering both formal institutions and organisational arrangements, as well as more informal institutional practices of actors. They are intended to help explore in more detail the initial observations made in D4.1.

i. Research question 1: Twin transition dynamics

The twin transition is often discussed through a technology-centred lens that highlights regions’ ability to develop or integrate technologies that are both green and digital (e.g., Bachtrögler-Unger et al. 2023; Faggian et al. 2025). Complementing this perspective, this WP adopts an explicit institutional and policy lens. Rather than focusing on technological capabilities or innovation outputs, it examines how the twin transition is shaped through changes in the institutional and organisational context of regional labour markets.

More specifically, this WP conceptualises the twin transition as the integration and coordination of green and digital agendas as reflected in policy frameworks, strategies, programmes, organisational arrangements, and actor practices. In this vein, it focuses on how impulses originating from both European and national policy frameworks and/or initiatives are interpreted, combined, and translated into concrete institutional and organisational changes at the regional

level, particularly in labour market and skilling domains. At the same time, it also takes into account the possibility of more bottom-up driven changes, initiated by actors at the regional level.

Analytical attention is therefore paid to whether the institutional and organisational change events depicted in the topologies in D4.1 relate to greening, digitalisation, or both, and how these change processes unfold across time, space, and in relation to each other. Where both dimensions are addressed in one event simultaneously, they are interpreted as institutional manifestations of a twin transition.

Recent research on the coupling of digital and green transformation agendas underscores the need for coordinated, place-sensitive policy approaches and alignment across governance levels, policy domains, and actor groups (Faggian et al. 2025; Gao 2025). At the same time, it remains unclear under which conditions and through which institutional and organisational arrangements regions are able to meaningfully connect digital and green transformation processes in practice. Existing studies predominantly point to policy- and funding-driven linkages that are promoted through top-down agendas and programme logics (e.g., Bianchi et al. 2024; Kovacic et al. 2024). However, it remains an open question to what extent such externally induced linkages translate into coherent practices at the regional level. This translation depends on how these couplings are interpreted, adapted, and institutionally embedded in specific regional contexts. Without such embedding, couplings may remain superficial or generate tensions between competing objectives and priorities.

Against this backdrop, Research Question 1 examines the extent to which regional actors achieve an institutional twin transition, how they translate green and digital agendas into coherent regional strategies and organisational practices, and how they manage potential goal conflicts between competing logics and priorities. In doing so, RQ1 considers both observable moments of coupling (as identified in the topologies developed in D4.1) as well as deeper changes in normative and cognitive orientations, which often unfold more gradually and implicitly but might significantly shape how and why actors initiate these changes in formal structures.

RQ1: *To what extent can a twin transition be observed at the regional level within the institutional context of the labour market, and what drivers and barriers shape these dynamics?*

The following guiding questions serve to sharpen the analysis by addressing actor constellations and interests, the nature and depth of institutional couplings, mechanisms of translation and brokerage, and the multi-level character of policy impulses:

- *Which actor groups initiated developments related to digitalisation and greening?*
- *What motivations, interests, or institutional pressures shaped these processes?*
- *To what extent are green and digital transformation processes linked at the institutional level, or kept separate?*
- *Can specific moments of coupling, translation processes, or bridging actors be identified?*
- *How were supra-regional policy impulses interpreted, adapted, or translated at the regional level?*
- *To what extent did regional actors actively reshape external transformation agendas?*

ii. Research question 2: Skilling-initiatives

The literature emphasises that the twin transition has significant effects on labour markets and skill requirements (Cedefop, 2025). Training and continuing education are therefore needed to mitigate adverse social effects of transformation and to reduce risks of skill mismatches and

exclusion (Bianchi et al., 2024). Place-sensitive transformation strategies are particularly essential in this regard given the geographically uneven social and economic consequences of the digital and green transitions (Diodato et al. 2023).

RQ 2 is thus closely linked to RQ1, which addresses the institutional emergence and coupling of digital and green transformation dynamics at the regional level. RQ2 focuses on the translation of these transformation dynamics into processes of skills development and labour market-related support. In this way, it addresses a core dimension of regional labour market resilience.

By examining the mechanisms through which structural transformation is translated into skills and qualification dynamics, RQ2 contributes to a better understanding of how regional labour markets develop the capacity to absorb change and limit risks of mismatches and social exclusion. A particular analytical focus lies on the temporal embedding of skilling initiatives within broader institutional transformation processes. The latter enables to better understand how timing and sequencing shape the effectiveness of skilling initiatives and their alignment with ongoing structural change.

Existing research suggests that regional skills ecosystems and industrial development strategies often remain structurally disconnected, limiting the capacity of regions to respond dynamically to transition pressures (Corradini et al. 2023). In addition, evidence on how skilling initiatives evolve regionally and which actors, processes and governance structures shape this remains thin (Faggian et al. 2025)

In line with the EU's broader Skills Agenda, RQ 2 considers skilling initiatives across all educational phases, i.e. from school and higher education to workplace learning. However, it is expected that up- and reskilling initiatives will be particularly central in the case studies. Up and reskilling is understood here, also in accordance with EU definitions, as the continuous, lifelong and life-wide development of competences across formal and informal learning contexts (Cedefop 2025).

Similar to RQ1, the analysis in RQ2 includes both observable changes (e.g., the implementation of new training programmes, continuing education offers, regional skills strategies, and sectoral training initiatives) as well as more informal changes that are not directly visible through institutional or organisational proxies (e.g., the development of new workplace learning cultures, occupational identities, or communities of practice).

RQ 2: *How do skilling initiatives evolve at the regional level in the context of the twin transition, and which drivers and barriers shape these processes?*

The following guiding questions serve to sharpen the analysis by addressing actor constellations and interests, translation mechanisms and temporal patterns, as well as the multi-level embedding of external impulses:

- *Which actor groups initiated regional skilling initiatives, and what were their motivations or constraints? Through which mechanisms did these initiatives emerge or fail to emerge?*
- *How can the temporal patterns identified the topology be explained? Why did skilling initiatives emerge late, in parallel, earlier, or remain absent in relation to broader greening and digitalisation dynamics?*
- *Do skilling initiatives responding to greening and those responding to digitalisation follow different logics, actor constellations, or mechanisms, or are similar drivers at play?*

- *How did national- or European-level policies, funding schemes, or qualification frameworks influence the emergence (or absence) of regional skilling initiatives, and how were these translated or adapted at the regional level?*
- *How are skilling initiatives shaped by the broader institutional context of the labour market (e.g., education and training systems, collective bargaining structures) in the case study region or country?*

d. Research design and implementation in D4.2

This chapter provides a brief overview of the research design and data collection for the topologies and their analysis as developed in D4.1. It then translated the two research questions that guide the analysis in D4.2 into a concrete research design and outlines its procedural operationalisation as well as specific implementation steps. This includes the development of a structured template provided to partners for conducting the in-depth analysis, as well as the implementation of this template in close interaction with the partners.

i. Research design and data basis established in D4.1

This deliverable builds on the research design that has been developed and implemented in D4.1, which provided the foundation for the establishment and description of the transition topologies. The design followed a processual, embedded case study approach, covering 13 regional case studies across different sectors and countries. It was based on qualitative data collected in close coordination with WP3.

The empirical basis consists of a triangulation of narrative interviews and document analysis. These two approaches enabled the detailed reconstruction of institutional change processes over time and how they shape regional labour market transformations. Case delineations were adapted slightly by each partner in terms of spatial and sectoral scope to capture relevant place-specific dynamics, while maintaining comparability across cases.

Subsequently, events representing key moments of organisational and institutional change were identified and categorized based on their temporal, spatial, and actor-specific characteristics. As the transition topology approach is based on a process-approach, the relevance of an event was not determined here by how often it was mentioned in the interviews of documents, but by the role it played for explaining the transition process.

The coded events were collected in harmonised case databases (integrating all coding results and linking them to their key sources) and afterwards visualised in form of transition topologies (with the Topology Visualizer). Subsequently, they were complemented by narrative case descriptions.

These central outputs of D4.1 form the starting point for Task 4.2. While D4.1 focused on the identification and visualisation of key events and the broad patterns emerging from them, D4.2 conducts an in-depth analysis of these patterns of institutional change by examining their micro-level dynamics and drivers.

Figure 1 provides an overview of the research design and implementation process underlying D4.1.

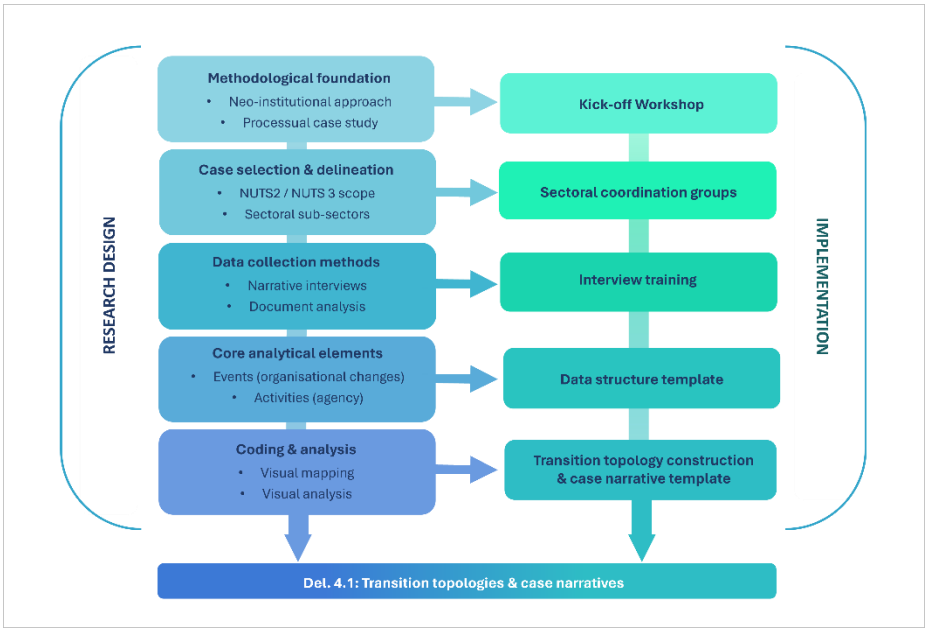

Figure 1: Research design and corresponding implementation steps in Task 4.1

ii. Processual operationalisation through the Case Study Template

The Case Study Template operationalises the analytical framework into a structured case analysis. It thereby ensures (1) a systematic reconstruction of event sequences and their underlying micro-dynamics, (2) the comparability of analytical outputs across cases, and (3) a consistent translation of the transition topologies into analytically interpretable patterns of institutional change.

The template is organised around the two main research questions, which represent the core analytical lenses for D4.2. For each research question, the template guides the partners through four-steps of analysis: i. pattern identification, ii. detailed empirical description of the underlying micro-dynamics, iii. analytical interpretation, and iv. visual depiction of these processes within the transition topologies.

Step 1 focuses on the identification of distinct patterns and temporal sequences of institutional change in the transition topologies developed in D4.1. This step thus serves to establish an initial categorisation of the developments at the regional level by asking partners to reflect on and classify the topologies developed for their respective case studies in D4.1 against a set of predefined heuristic patterns. The latter were derived from the two research questions presented above. While cases may show a single pattern throughout the period studied, they might also move from one pattern to another, thus containing several different temporal sequences.

For RQ1, four patterns of Twin Transition dynamics are distinguished based on the temporal and institutional relationship between greening and digitalisation:

- **Pattern a**: Greening-related changes clearly predominate
- **Pattern b**: Digitalisation-related changes clearly predominate
- **Pattern c:** Both types of changes occur, but predominantly separately
- **Pattern d:** Both types of changes occur in an integrated manner

Similarly, for RQ2, four patterns of skilling initiative development are distinguished based on the temporal relationship between skilling initiatives and the broader transition dynamics:

- **Pattern a:** Changes in the form of reskilling and upskilling initiatives occur only later, after institutional change driven by greening and/or digitalisation has already taken place in the labour market context
- **Pattern b:** Skilling initiatives precede the transition
- **Pattern c:** Skilling initiatives are almost entirely absent or very rare
- **Pattern d:** Skilling initiatives develop in parallel with the transition

Step 2 constitutes the core component of D4.2 by asking the partners to develop a detailed reconstruction of the identified patterns (in step 1) based on the collected event data. This includes a systematic description of key events and, in a second step, an in-depth analysis of the micro-dynamics at the level of actors and their interactions that explain how and why these patterns emerged.

Hence, this step involves not only the empirical description of the observable changes captured in the topologies (e.g., the implementation of new legislation or the establishment of new organisations), but also the analysis of associated, often less visible informal dynamics (such as changes in collective perceptions, shared values, or cognitive orientations), which often precede formal changes. The events captured in the topologies provide important indications that these normative or cognitive shifts extend beyond the individual level, for instance, when actors actually invest resources in the implementation of new ideas by founding a new organisation.

In this second step, partners are thus asked, where necessary, to complement the narratives by additional evidence from interviews and document analysis to strengthen the analysis. In cases where relevant data gaps emerge, partners are asked to explicitly document and flag these as inputs for follow-up discussions in the context of the focus groups in D4.3.

Step 3 then requires synthesising the empirical findings into a more abstract, analytical interpretation of the case regarding the respective research question. Building on the reconstructed patterns and micro-dynamics, this step thus formulates a concise explanation of the main drivers, barriers, and mechanisms of institutional change identified in each case.

Step 4 then focuses on the visualisation of these micro-dynamics within the transition topologies and the identification of main sequences, and patterns emerging from the analysis. Here, partners are asked to identify relevant temporal linkages between events or clusters of related events (so-called “streams of events” resulting from shared micro-dynamics). This step is supposed to support the visual representation and further refinement of the transition topologies for the focus groups in D4.3.

For both research questions, the template thus follows a consistent analytical logic: starting from structured pattern identification, moving to detailed empirical reconstruction, and eventually leading to an interpretative synthesis and visualisation of key dynamics.

iii. Workflow and outcomes of the in-depth analysis

This section describes the analytical workflow and resulting outputs of D4.2.

The template for D4.2 was distributed to partners with instructions to complete it based on D4.1 topologies on April 15, 2026. Partners were requested to complete Step 1 and 2 of both research

questions, with bilateral meetings scheduled to jointly review drafts and allow targeted revisions of the analysis. For this analysis, additional document and interview analysis was conducted where necessary to update the transition topologies resulting from D4.1. After partner revision of the in-depth analysis, BOKU revised the templates and integrated the analysis in the deliverable. This workflow ensured early identification of gaps and alignment on analytical depth and structure across cases.

The outcome are case-level analytical narratives, structured around the two main RQ, elaborating in detail the micro-dynamics in each case. These build a basis for the focus groups in D4.3 and for cross-case comparison in D4.4. The described micro-dynamics in this deliverable allow for the highlighting of streams (linked event sequences), refining temporal linkages, and visually emphasising mechanisms that underpin institutional change for T4.3. The refined topologies can serve as communication tools for stakeholder engagement in the focus groups. These focus groups will also serve as an opportunity to validate the findings and if necessary to complement the data gaps.

3. Results

This section consists of the in-depth analysis of the institutional and organizational change processes related to the twin transition and the transformations of regional labour markets in the case studies. In the following, the results for each case study are presented, structured by sectoral focus. The case delineation (both spatial and sectoral) follows the one established under Task 4.1. For each case study, the in-depth analysis is structured around the two research questions and Step 1-3 (patterns, micro-dynamics and analysis) of the provided template.

The interview numbers referenced in the text refer to the sequence of interviews within each case (as they will be made available by WP 3) and represent selected key references used in the analysis. Further event-level source references to interviews and documents supporting the reconstruction of the process and its underpinning dynamics, are archived in a dedicated Excel database for each case.

a. Food Sector

The Food Sector is the focus of three case studies by the partners BOKU, FHNW and UoC. The updated data basis for the results of each case is summarized below (Table 1):

Table 1: Data basis for Task 4.2 in the Food Sector

BOKU	FHNW	UoC
16 stakeholder interviews - Regional development agency (3) - Academia (3) - VET provider (3) - Public employment service - Private firm (3) - Association (2) - Industry service provider	7 stakeholder interviews - Tourism agency - Academia - Cultural tourism office - VET provider - Administrative district - Private firm - Association	8 stakeholder interviews - Local government/inter-municipal organisation - Academia (2) - Research and education institute - Private firm/entrepreneur (4)

i. Vulkanland (BOKU)

RQ1: To what extent is a Twin Transition emerging at the regional level within the institutional context of the labour market?

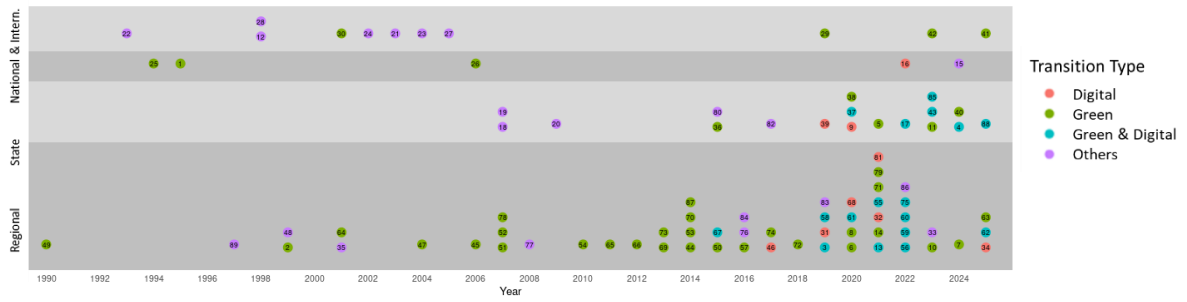

Figure 2: Transition topology depicting institutional changes related to greening and digitalisation across multiple spatial scales in the food sector in the Vulkanland, Austria (1990-2023).

In the food case in the Vulkanland region, the topology (Figure 2) depicts that greening-related changes clearly dominate at first (pattern a), particularly at the regional level during the period from 1990 to 2014. From around 2015 onwards, however, a differentiation of this pattern can be observed: in addition to ongoing greening-related changes, digitalization-related changes begin to emerge at the regional level (pattern c), along with some changes that integrate both processes (pattern d).

Overall, the case thus reveals a temporal sequence in which greening-related developments initially prevail, followed, starting around 2015, by a combination and, in some instances, even an integration of greening- and digitalization-related institutional and organizational changes at the regional level.

Description of the Patterns, Sequences and the underlying Micro-Dynamics in the Empirical Case

In the food case in the Vulkanland region, numerous institutional and organisational changes related to greening and digitalisation can be observed over time, involving different actor constellations, organisational forms, and governance levels.

Early greening-related developments at the regional level date back to the 1990s, when municipal cooperation laid the groundwork for what was later formalised as the “Steirisches Vulkanland” brand and association in 1999 (Event 2). Following Austria’s accession to the EU in 1995, increasing regional competition and access to EU LEADER funding supported the launch of this regional initiative, which built on the idea of “giving value” to local products as elaborated by a regional development program manager (Interview04). The process was primarily initiated and driven by the regional development agency in close collaboration with local municipalities and leading companies such as Zotter and Gölles. From the outset, the regional brand focused on culinary production and craft-based activities (Interview04).

Over time, these greening-oriented developments materialised in a range of formats and networks, such as the “Culinary Fall” and the Masterclass Evenings (Event 64 and Event 87), established in 2014, which brought together local producers and promoted regional quality, authenticity, and short value chains (Interview04). Alongside these regional initiatives, changes at the firm level can also be observed. For example, the introduction of organic certification at Zotter in 2006 (Event 45) illustrates how such developments were reflected in organisational practices within companies (Interview13).

Developments related to digitalisation emerged later and followed a different temporal pattern. From around 2015/2017 onwards, the first changes became visible within local food processing companies, particularly medium- to large-sized firms. These included the integration of robotics into production processes (Event 46, Interview13) and the establishment of organisational units such as automation departments (Event 31; Interview05). These developments were associated with internal management decisions, innovation orientations, and broader industry requirements such as quality standards and production modernisation (Interview13&05). Most firm-level changes focused on digitalisation, with only limited overlap between digitalisation and greening-related activities.

In 2019, several developments further shaped this trajectory. At the Styrian level, a dual Master's programme in Food Product and Process Development was introduced (Event 39; Interview09), focusing on food processing technologies, process innovation, and product line optimisation. In the same year, the Network for Food Technology (Event 3) was established at the regional level (Interview04). The network built on the concept of "Culinary 2.0," aiming to further develop existing regional activities in the food sector and deepen value creation, including through digitalisation. It brought together regional firms, drew on existing cooperation structures (e.g. Event 64 and Event 14), and incorporated expertise from research institutions such as TU Graz. The initiative was supported by funding mechanisms at the Styrian level.

From 2021 onwards, developments increasingly addressed both greening and digitalisation within regional strategies. The Vision 2040 (Event 13) outlined the overarching strategic orientation of the Vulkanland region and linked digitalisation to sectors such as energy and the bioeconomy (Interview04). This was followed by the Regional Development Strategy 2021–2027 (Event 55), which included the development of digital skills as a strategic objective. In 2022, the Local Development Strategy (LEADER) for 2023–2027 (Event 56) further emphasised the role of digital approaches in addressing sustainability challenges in the food sector and defined corresponding funding priorities, including support for projects linking agriculture and food processing (Interview04).

At the same time, differences in governance and funding structures can also be observed. While regional strategies increasingly referred to digitalisation, certain activities, such as those related to the Food Technology Network, were linked to funding and support structures at the Styrian level rather than being fully integrated into regional funding schemes.

In 2024, these developments were complemented by the establishment of the Styrian Food Hub (Event 4). This new network initiative at the Styrian level expanded funding opportunities and support structures for projects in areas such as artificial intelligence and digitalisation (Interview06). The connection of regional initiatives, such as the Food Technology Network, to this higher-level organisation facilitated access to additional resources and expertise for local actors beyond the regional level.

Overall, the case shows that greening- and digitalisation-related developments emerged at different points in time, involved different types of actors, and were organised across multiple governance levels, including the regional and Styrian state level.

Analysis of the Twin Transition Dynamics

The case shows that greening and digitalisation followed distinct and initially unconnected development logics. Greening evolved as a regionally coordinated, value-based process, driven by intermediary actors and embedded in regional networks, with gradual diffusion into firm-level

practices. In contrast, digitalisation developed as a firm-driven and externally oriented process, shaped by technological and sectoral pressures and largely disconnected from regional coordination.

The interaction between these trajectories was actively facilitated by the regional development agency, which acted as a bridging actor by linking digitalisation to existing regional value frameworks. This reflects a coupling process, in which new technological agendas were integrated into established regional structures and networks.

However, this integration remained partial. While digitalisation was increasingly reflected in regional strategies, its implementation relied heavily on supra-regional funding and support structures. These developments highlight, a tension between the broader value-oriented regional development efforts and higher-level funding structures that are more attuned to support technological advancements and innovation.

In summary, the transition topology reveals that the twin transition in the food sector of the Vulkanland region has not emerged as an integrated process, but rather as a sequential and asymmetrical process, with distinct drivers and timelines.

RQ2: How are upskilling and reskilling initiatives developing in the context of the Twin Transition?

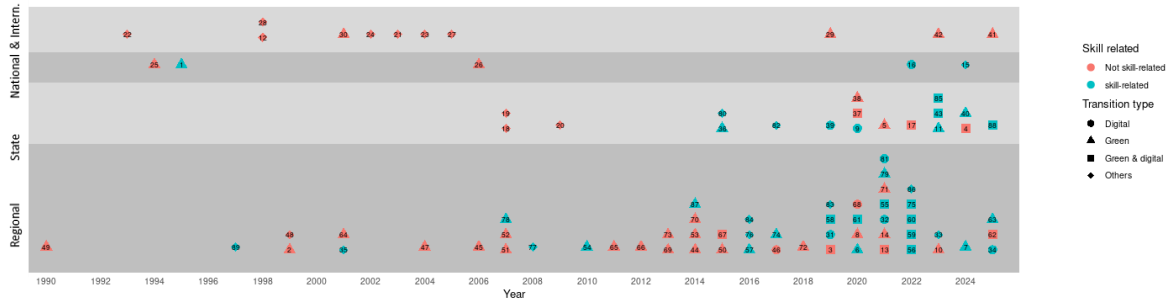

Figure 3: Transition Topology depicting institutional changes related to skill (and non-skill)-related initiatives as well as transition type across multiple spatial scales in the food sector in the Vulkanland region, Austria (1990–2025).

In the food case in the Vulkanland, the topology (Figure 3) shows that the first skilling initiatives developed in parallel with greening-related changes (Pattern d), particularly at the national and regional levels. In a later phase – starting around 2017 – a shift becomes apparent, however: at the regional level, skilling initiatives then emerge much more prominently after institutional changes in the labor market driven by greening and digitalization have already taken place (Pattern a). This suggests that skilling measures are increasingly being implemented in response to requirements created by the transition. Overall, therefore, a temporal sequence can again be observed here in which a more parallel occurrence is followed by a more reactive pattern.

Description of the Patterns, Sequences and the underlying Micro-Dynamics in the Empirical Case

Education was early on recognized by regional actors as an integral component of the regional development strategy and closely linked to the broader process of regional identity building and the effort to “give value” to local products, knowledge, and production practices in the context of the first LEADER funding period (2007-2013) (Interview04 &16). This role of education gained increasing strategic importance as regional actors gradually reoriented their development approach in the second LEADER funding period (2014-2024) towards a stronger emphasis on resilience, everyday embedding of regional strategies, participation, and knowledge-based capacity building (Interview04).

Early regional change processes in this regard were thus predominantly driven by multi-actor constellations embedded within the region's development organizations. As one interviewee from the regional education coordination noted, "Ensuring humanity's future-readiness by starting with ourselves is the top priority." reflecting a shared normative framing that was actively taken up and reinforced within regional development initiatives (Interview16). This orientation was subsequently translated into concrete organisational changes, for example, the establishment of the Education and Innovation Fund in 2001 (Event 35) and the creation of the Vulkanland Academy in 2010 (Event 54), which aimed to introduce a distinctive form of education that combines experiential learning, regional knowledge transfer, and community-based competence development (Interview16). Subsequent developments continued to emphasized accessible educational offerings on regionality and sustainability such as the "Meisterkulturabende" (Event 87), which regional actors integrated as a recurring format within the licensing and certification process of the Vulkanland brand (Interview16). As a regional development actor explained, these events were used both to raise awareness of emerging topics and to explore whether particular issues warranted further development and more in-depth engagement within the region. They also reinforced awareness of jointly defined regional values and quality standards as integral to network membership. In parallel, regional companies established internal training in sustainable sourcing, organic certification, and quality assurance (Event 78), linked to internal greening-oriented restructuring.

At the federal state level, several changes in the mid-2010s influenced regional skilling provision and related initiatives, addressing more general structural and institutional foundations. The establishment of regional coordination points for Educational and Career Guidance (BBO), including in the Vulkanland (Event 84), followed by a statewide BBO strategy in 2017 (Event 82), enabled and informed subsequent regional organizational changes. For example, the regional development strategy adopted in 2021 (Event 55) emphasized, for the first time, the importance of lifelong learning and framing "future skills" not only as technical competencies, but as an integrated combination of knowledge, values, and awareness, closely aligned with the above-mentioned educational philosophy of the Vulkanland Academy. As a direct consequence of the coordination point, the first Regional Educational and Development Plan was enacted in 2022 (Event 60), serving as a management tool that allows the region to engage with federal organizations on a different level. Notably, the Vulkanland is the only region in Styria to have drafted a regional educational and development strategy (Interview16). In addition, related to the establishment of the regional coordination point, the Career Fair for Professional Development (Event 81) further underscored the need for continuing education offerings. While greening and digitalization are referenced in the aforementioned regional events, these developments primarily established the institutional and organisational infrastructure through which such transformation-related skilling initiatives were later coordinated and integrated across actors.

After 2019, several initiatives related to the digital and in the wider sense twin transition with a specific focus on skill development were initiated at the regional level. These developments build on previously established networks (see RQ1), such as the Network for Food Technology (Event 3) in cooperation with the regional development agency. For instance, pilot curricula at the College of Higher Vocational Education (Events 6 and 7) aimed to meet the skills demand of the culinary sector established in Vulkanland (Interview09). Similarly, initiatives such as the Technology Games (Event 33) in 2023 and Tech for Children (Event 34) in 2025 - originally initiated by the Technology and Crafts Cluster (Event 61) and organized in cooperation with the Network for Food Technology - address the need for technical and digital skills while increasing the visibility of technical professions for children and youth (Interview16). These initiatives also

suggest alignment between sectors with similar skill needs and a shared recognition of the need and willingness for coordinated action.

While most skilling initiatives related to the digital and twin transitions have focused on youth education, regional actors increasingly recognize the need for upskilling and reskilling of workers (Interview05&06). One notable event explicitly addressing this demand in the food sector was the formation of a qualification alliance in 2021 (Event 32), involving members of the Network for Food Technology. Similarly, to developments described under RQ1, employee training is increasingly organized in linked to the state level through the Styrian Food Hub, which launched an event series on digitalization in 2025 (Event 88). In this context, the role of LEADER actors and the regional development agency in repeatedly establishing such cross-level linkages and securing additional funding to support bottom-up initiatives within the Vulkanland region was highlighted in several interviews.

Analysis of the Dynamics of Skilling Initiatives

Greening-related skilling initiatives emerged early, were strongly embedded in regional development structures, and took place mainly outside the formal education system. They were driven by the regional development organisation, building on the region's strategic priorities and regional identity formation processes, rather than on more standardized vocational education and training systems. In parallel, firms developed internal training activities around organic certification and sustainable sourcing, which however remained largely disconnected from wider regional education and training offers.

Skilling related to digitalisation and the twin transition emerged later, in response to institutional changes in regional strategies and governance arrangements driven by digitalisation processes. It was driven primarily by regional company networks in cooperation with the regional development organization. The focus of these initiatives remains on initial skilling and youth education, while the need for adult re- and upskilling is increasingly recognised but not yet fully addressed. Few institutional and organisational changes have directly targeted this gap, and economic and public actors increasingly depend on state-level funding instruments and cluster-based formats, which are not primarily tailored to the needs of SMEs.

ii. Val Poschiavo (FHNW)

RQ1: To what extent is a Twin Transition emerging at the regional level within the institutional context of the labour market?

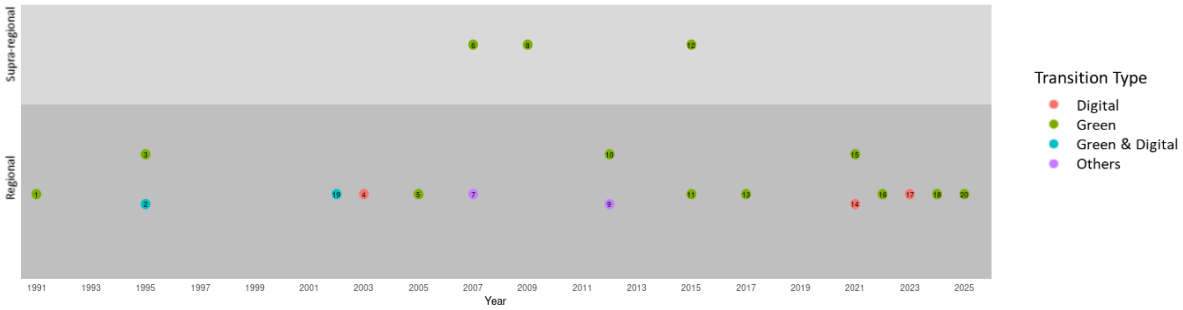

Figure 4: Transition Topology depicting institutional changes related to greening and digitalisation across multiple spatial scales in the food sector in Val Poschiavo, Switzerland (1991-2025).

As illustrated in the transition topology (Figure 4), in the Val Poschiavo case, greening- and digitalisation-related changes do not emerge as clearly separate or sequential processes but are closely intertwined from an early stage on (pattern d). Initial greening related developments (in organic agriculture) can be observed in the early 1990s, which are combined with early education- and digitalisation initiatives. Over time, both processes increasingly interact and reinforce each other, however the pattern tends more towards a parallel development of both transitions (pattern c), rather than a sequential shift from one dominant process to another. Hence, the case reveals a co-evolutionary trajectory in which all dimensions of the transition are closely aligned and mutually supportive.

Description of the Patterns, Sequences and the underlying Micro-Dynamics in the Empirical Case

In the Val Poschiavo case, the development of the twin transition is characterised by an early emergence of greening- education-, and digitalisation-related initiatives, followed by a gradual process of institutionalisation and integration across sectors and governance levels.

Greening-related developments can be traced back to the early 1990s, when Daniele Raselli und Elmo Zanetti initiated the conversion to organic herb production and started breeding fallow deer. The latter was formally certified in 1993 (Event 1). This pioneering step played a crucial role in demonstrating the economic viability and ecological value of organic farming in the region, thereby encouraging other actors, such as the Caseificio Valposchiavo, to adopt similar practices (Event 3; Interview01). These early initiatives contributed to the formation of a shared understanding of sustainable agriculture as a viable development pathway for the valley. The establishment of the working group “Dal campo alla tavola” (Event 5) in 1998 further reinforced this trajectory by promoting cooperation between farmers, processors, and the hospitality sector. It thereby strengthened regional value chains and embedded sustainability within broader economic activities. The Programma di sviluppo regionale (PSSR, Event 6), developed in 2007 with cantonal participation, provided the broader institutional framework within which these regional food and agricultural initiatives could be anchored and scaled.

At the same time, digitalisation-related developments emerged through the launch of Progetto Poschiavo (Event 2). This initiative aimed to overcome the geographical isolation of the valley by fostering digital infrastructure and competencies. In this way, this initiative played an important role in shaping the region’s capacity for innovation, not only by introducing technological tools, but also by initiating educational programs and as such influencing the mindset of local actors, including businesses, public administration, and civil society. The initiative can thus be seen as the initial driver of the green, digital and educational transition in the region. The development of digital literacy and project management capabilities facilitated new forms of collaboration and networking, which would later prove essential for the integration of sustainability and economic development initiatives. A municipal head active in the valley emphasised the lasting cultural impact of the project as follows: “we had the highest number of internet connections in Switzerland in our valley – it was very, very innovative, and you can still feel it now, even though the project has been finished for 25 or 20 years” (Interview 01). This long-term effect on local digital- and learning culture was also confirmed by a regional development consultant who noted that the project resulted in “practically every household equipped with email before the same level was even reached in Swiss cities”. In this way, a community was created that remained networked and engaged with innovation across geographical boundaries (Interview 07).

Over the following decade, these parallel developments became increasingly institutionalised. The creation of digital communication platforms such as “Il Bernina” in 2003 (Event 4) contributed to strengthening regional identity and facilitating information exchange across sectors. At the

same time, initiatives such as the Watercourse Development Concept (Event 8) and the Centro Tecnologico del Legno (Event 9) illustrate how sustainability considerations were embedded within broader regional development strategies, linking ecological goals with economic and technological innovation.

A key moment regarding the coupling of greening and digitalisation happened in 2012, namely, the introduction of the "100% Valposchiavo" initiative (Event 10). This project was aimed at creating closed regional value chains, by bringing together actors from agriculture, food processing, and tourism within a coordinated initiative. It built on earlier developments related to both sustainability and digitalisation. On the one hand, it relied on digital tools for coordination and marketing, while on the other hand, it reinforced the region's commitment to organic production and local value creation. The subsequent introduction of the "Fait sü in" label (Event 11) and the Slow Train initiative (Event 12) in 2015 extended this integration of greening and digitalisation by creating shared branding and experiential formats that linked food production, tourism, and regional identity. In this sense, these developments together are an example of how previously distinct processes were combined into a more integrated development strategy. A berry producer and participant in the initiative described how this enabled a shift in cooperative working practices among the actors: "before this project existed, we went to the markets with our products and the tourist office went to the tourist fair with brochures and beautiful pictures – now we sometimes go together and sell not only pictures and brochures, but also products and the stories behind them" (Interview06). This joint presence in external markets illustrates the initiative's success in bringing together initially separated actors and efforts. It also shows how the initiative functioned as a practical coupling mechanism between the green and digital strands of the regional transition.

In the years that followed, this integration between greening and sustainability related developments deepened further. Due to initiatives such as the Mercato Valposchiavo B2B digital platform (Event 14) and Smart Valley Bio (Event 15) digital technologies became increasingly embedded within the regional food system, enabling new forms of distribution, coordination, and production. The Azienda Agricola Digitale project (Event 17), launched in 2023 by Polo Poschiavo, further contributed to this development by directly supporting farms in adopting digital tools. At the same time, sustainability-oriented projects, including the Swisstainable Destination certification (Event 16) and the WATERWISE initiative (Event 18), continued to expand the ecological dimension of regional development. The fruttipertutti project (Event 13), launched in 2017, similarly linked biodiversity goals with community engagement in the region. These developments were supported by a combination of local initiatives and external funding frameworks; the latter, which were, however, actively interpreted and adapted by regional actors.

Overall, the case shows that the twin transition in Val Poschiavo is not the result of two independent processes that are later combined, but rather of a long-term co-evolution of digitalization and greening related processes. It furthermore makes apparent that this development is driven by a combination of pioneering actors, intermediary organisations, and collaborative networks. Notably, early initiatives create the conditions for subsequent developments.

Analysis of the Twin Transition Dynamics

The Val Poschiavo case demonstrates a form of twin transition in which greening and digitalisation are closely intertwined and mutually reinforcing. Unlike cases where the two processes follow distinct trajectories and are only later aligned, the developments in Val Poschiavo arecharacterised by an early coupling of sustainability-oriented and digital initiatives.

Greening-related changes initially emerged through locally driven, sustainability-oriented initiatives. This was particularly the case in the field of organic agriculture, where these initiatives were underpinned by strong regional cooperation and a shared commitment to sustainable development. Digitalisation, in contrast, was introduced through targeted efforts to overcome structural disadvantages related to geographical isolation, most notably through the Progetto Poschiavo initiative. However, rather than remaining a separate trajectory, digitalisation quickly became embedded within broader regional development processes, providing the infrastructure and competencies necessary to support and scale sustainability initiatives.

A central feature of the case is the role of regional actors in actively linking these two processes. Organisations such as Polo Poschiavo and other intermediary bodies function as bridging actors that integrate digital tools into existing sustainability-oriented frameworks, thereby facilitating the emergence of synergies between the two processes. This bridging role was made possible in part by the valley's distinctive mix of assets. The digitalisation dimension was equally important. At the same time, developments at higher spatial levels, including cantonal and European funding programmes, provide important resources and frameworks that are selectively adapted to the regional context.

Despite this high level of integration, certain tensions can be observed, particularly in relation to the reliance on external funding structures and the potential limits to scalability beyond the specific regional context. Nevertheless, the overall trajectory suggests that the twin transition in Val Poschiavo has developed as a cumulative and deeply embedded process, in which digitalisation acts as both an enabling condition and an accelerator of sustainability-oriented change.

RQ2: How are upskilling and reskilling initiatives developing in the context of the Twin Transition?

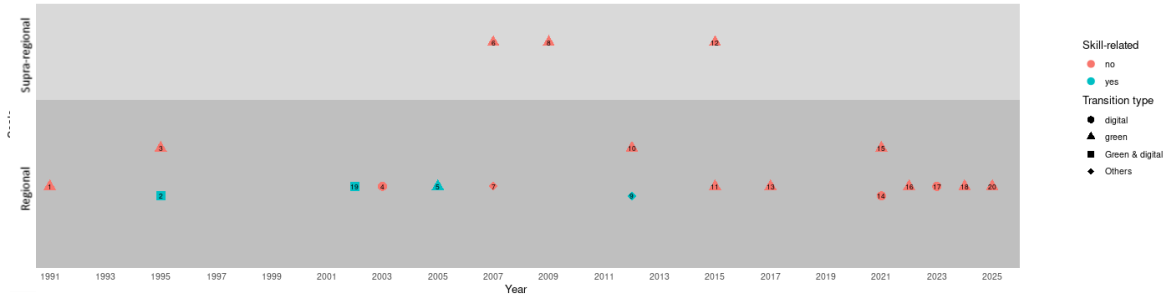

Figure 5: Transition Topology depicting institutional changes related to skill (and non-skill)-related initiatives as well as transition type across multiple spatial scales in the food sector in Val Poschiavo, Switzerland (1991-2025).

In the Val Poschiavo case, explicit upskilling and reskilling initiatives are largely absent from the observed transition processes, as the topology (Figure 5) shows. While early on numerous institutional and organisational changes related to skilling are observed (pattern d), later on skilling initiatives become more rate (pattern c). The case thus corresponds most closely to a pattern in which skilling initiatives are rare or largely absent, at least in their explicit and institutionalised form.

Description of the Patterns, Sequences and the underlying Micro-Dynamics in the Empirical Case

Skilling initiatives occur early on and primarily in an implicit and embedded manner, rather than through dedicated training programmes or institutionalised forms of education.

From the early stages of the transition, actors in the region acquire new knowledge and skills through their direct involvement in projects and collaborative initiatives. For example, the shift to organic agriculture (Events 1, 3) requires farmers to develop new forms of agronomic knowledge and production practices, while initiatives such as "Dal campo alla tavola" (Event 5) foster learning through cooperation across different sectors. Progetto Poschiavo (1990-1999, Event 2), played a foundational role in shaping the region's capacity for innovation, not only by introducing technological tools, but also by initiating educational programs and as such influencing the mindset of local actors, including businesses, public administration, and civil society. The development of digital literacy and project management capabilities facilitated new forms of collaboration and networking. Similarly, the introduction of digital technologies through Progetto Poschiavo contributes to the development of digital competencies among businesses, public administration, and civil society actors. A regional development consultant who was closely involved in the valley's transformation highlighted the democratising character of this early learning process: "none of us were familiar with these technologies, regardless of whether you were a historian or had a university degree … it was relatively new for everyone – and yes, that was an almost unique opportunity. It was distributed very democratically at the time" (Interview07). This points to how the absence of existing hierarchies of digital competence created an unusually open context for collective, practice-based skill formation.

Over time, these processes of learning become increasingly embedded within regional networks and projects. Initiatives such as Smart Valley Bio and Azienda Agricola Digitale (Events 15,17) further extend these dynamics by encouraging actors to adopt digital tools in their everyday practices, thereby reinforcing learning-by-doing and peer-based knowledge exchange. In this context, skill formation is closely linked to participation in collective activities and the practical implementation of new technologies and organisational forms.

Developments at higher spatial levels play a supporting role by providing funding and project frameworks, but they do not appear to directly promote formalised training structures. Instead, regional actors adapt these external resources to their specific needs, integrating them into ongoing initiatives without establishing separate skilling institutions.

Overall, the case suggests that skill development in Val Poschiavo is highly decentralised and practice-oriented, relying on informal mechanisms of learning rather than formal education or training systems.

Analysis of the Dynamics of Skilling Initiatives

The dynamics of skilling in Val Poschiavo are characterised by a strong reliance on implicit and practice-based forms of learning. Rather than being driven by dedicated policies or institutional frameworks, skill development emerges as a by-product of broader processes of institutional change, particularly those related to greening and digitalisation. This observation was also supported by one policy maker, who argued that formal digital training courses miss deeper requirements: "digital transformation skills are almost irrelevant at first glance. For me, the foundation is a mindset and cultural change … the whole culture that used to prevail, for example with hierarchical structures, top-down management, process thinking, no agility – this is the foundation that needs to be developed first" (Interview02). This emphasis on mindset over technical skills aligns closely with the embedded, participatory mode of learning observed throughout the Val Poschiavo case.

Overall, it can be concluded that this approach comes with certain advantages, such as allowing flexible and context-specific learning and thus learning that is closely aligned with the needs of local actors. Yet, it also provides some challenges. In particular, the absence of formalised training structures may limit the scalability and long-term sustainability of these developments. And it needs to be considered that these challenges may become more prevalent admits increasing technological complexity and growing demands for specialised skills.

The case therefore highlights a potential tension between the effectiveness of informal, embedded learning processes at the local level and the need for more structured approaches to skill development in order to support future growth and adaptation.

iii. Crete (UoC)

RQ1: To what extent is a Twin Transition emerging at the regional level within the institutional context of the labour market?

Figure 6: Transition Topology depicting institutional changes related to greening and digitalisation across multiple spatial scales in the food sector in Crete, Greece (2001-2026).

In the topology (Figure 6) for the food case for the region of Crete we can observe two patterns of changes. In the first period, 2001-2012, we see that very few changes take place, that the vast majority of them are green-related and that they mostly take place in the international and national level, though there are some initiatives at the regional level (pattern a). After 2013 and until 2026, the number of events increases rapidly and we see them trickling down to the regional level. After 2013 the type of events also changes, since digital-related and twin-related events also start to appear (pattern c and pattern d).

Description of the Patterns, Sequences and the underlying Micro-Dynamics in the Empirical Case

The first event related to the green transition took place in the regional level in 2001, when the Association of Olive-Growing Municipalities of Crete (SEDIK) was created as an inter-municipal governance organization bringing together municipalities involved in olive production (Event 1). Municipal authorities collectively established the organization to support producers, disseminate practices, and respond to sectoral challenges such as sustainability requirements and modernization pressures. This indicates that olive producers understood the need to modernize their practices and make them greener in order to keep up with the market and the legislation. After that, two EU policies were introduced, the CAP reform in 2003 (Event 2) and the mandatory Implementation of HACCP & ISO-based Food Safety Systems in 2004 (Event 3). The former linked direct payments to farmers with compliance with environmental protection, food safety, plant health and animal welfare rules, while the latter led to systematic digital record-keeping, traceability systems, and formalized monitoring protocols across the food chain, which

pushed for more digitalization. In 2005 an early green transition step took place by an olive mill was the upgrade of the olive mill boiler system to operate using olive processing residues (olive kernel biomass) (Event 4). This happened mostly for energy saving purposes (Interview02). In 2007, the Expansion and Formalization of Organic Product Certification Systems takes place as part of the EU Organic Regulation framework (Event 5) and in 2009 the Directive 2009/128/EC established an EU framework to achieve sustainable pesticide use by reducing risks to human health and the environment and promoting Integrated Pest Management (IPM) and alternative non-chemical methods (Event 7). In 2010 we noted the environmental modernization of more olive mills (Event 10), pushed by EU regulations concerning plant protection, production standards, environmental protection, and traceability. In 2010, a EU directive was voted regarding industrial emissions (Event 11) and was transposed into the Greek law as the transposition of the Industrial Emissions Directive (2010) (Event 12) and the Greek Environmental Licensing Law (2011) (Event 13). Finally, in 2013, the Common Agricultural Policy (CAP) was reformed, strengthening environmental obligations and making environmental sustainability a central pillar of agricultural policy (Event 15). Concluding, this period is characterised by a handful of small regional changes aiming towards green transition and many more national and international changes in the laws aiming to push towards green and digital changes. We might say that it is a "preparatory" period towards the next period, which is the period of changes in the food sector.

The second period from 2014 and 2026 is the period where many events and changes are observed in the topology (Figure 6). Specifically, we see an increase in the events happening in the regional level, as well as in the national and international level. The first events we observe (2015) are the increased digitalization in the olive processing units, such as the digital mapping of farms enabling planning, monitoring and subsidies (Event 16) and the increasing digitalisation of agricultural land management and farmer participation systems (Event 18), which reflect the implementation of EU Common Agricultural Policy (CAP) digital administration, including online declarations, subsidy platforms and compliance systems (Interview05). Nevertheless, some digital changes took place to increase efficiency, such as the commercial management software introduction by a visitable winery and olive processing facility (2015) (Event 22) (Interview07). The same company later (2018) implemented a specialised digital production management system adapted specifically for olive mills, co-developed with a local technology company and enabling full production traceability (Event 31). This system enabled the company to upgrade from ISO 9001 to FSSC 22000, an internationally recognized food safety certification system, due to traceability implementation (Event 32), giving them more market recognition (Interview07). Through publicly funded programs they also (2019) updated their website and launched an e-commerce platform (Event 33), and they (2020) implemented a CRM system improving customer management, exports, and operational coordination (Event 39).

The same enterprise entered national and EU-supported green transition schemes and the Greek Development Law investment framework in 2023 to install photovoltaic systems (Event 46; Interview07). Similar actions were taken by other actors, such as the agricultural cooperative of Palaia Roumata, whose olive mill also installed photovoltaic systems through an ESPA (European Structural and Investment Funds) programme of the Region of Crete in 2018 (Event 28; Interview02). This event took place after a total reform of the olive mill initiated by the new administration in 2016 and finished in 2018 (Event 24). Reforms included the removal of water from processing (two-phase system), the replacement of crusher, washer, malaxer and the introduction of pallet boxes instead of plastic feed sacks (Interview02). In 2018 the cooperative was recognised as a producer organisation, which enabled them to participate in the Operational Programme of Olive Oil Producer Organisations (ΟΕΦ) (Event 27) under the Greek Ministry of Rural Development and Food in order to modernize their olive processing facility (Event 26). Moreover, in 2015, Creta Farms established an internal environmental department (Event 14), in response

to new EU-driven Greek environmental legislation (Events 12 & 13). Following this change, in 2020, they restructured key production-related processes, including energy management and handling of biological by-products (Event 34; Interview02).

It is worth mentioning that a greater valorisation of agri-food by-products can be observed since 2015, especially in olive oil and processing where olive kernels are starting to be utilized (Event 19). In 2020, digital Training & E-Governance were accelerated due to the pandemic and digital pest monitoring and precision agriculture pilots were introduced. Moreover, the Farm to Fork Strategy which forms the food-system pillar of the European Green Deal was adopted in order to create sustainable food systems by reducing pesticide and fertilizer use, improving environmental performance, promoting precision agriculture, digitalisation and traceability across agricultural value chains (Event 39). Additionally, in 2023, the CAP was renewed replacing previous cross-compliance and greening systems with Enhanced Conditionality, integrating environmental and climate obligations into a single framework combined with voluntary Eco-Schemes supporting sustainable and climate-friendly farming practices (Event 47). Finally, it is worth mentioning that several research projects have been taking place in the recent years, such as the Interreg Project "EcovineGOALS", which focused on the agroecological transition of vineyards in Crete (Event 40), the Horizon Project "ChameLEON", which was a pilot drone-based livestock monitoring programme (Event 44) and the Precision Irrigation Pilot programme (2024) (Event 47). One of the interviewees also mentions that the and leaf diagnostic lab is seeing a "boom" in farmer participation since 2018, which indicates a behavioural shift toward data-based fertilization and water management (Event 30; Interview05).

Analysis of the Twin Transition Dynamics

In the food case in Crete, Greece the green changes precede the digital ones by several years. In the early phase, firm-level greening takes place as a reaction or anticipation of EU- and national regulation, in combination with wider industry developments with regards to traceability.

From 2015 onwards digitalization is also increasingly implemented regionally, mainly driven by traceability requirements by legislation and industry. Overall, a large number of regional changes (both green and digital) are driven by national and international funding programs, regulation and industry requirements. Additionally, some of them took place to improve efficiency in the business, or to cut costs and some were mandatory for compliance with the Greek law.

Importantly, from 2015 onwards several businesses are starting to invest in the agrotourism (e.g. visitable winery and oil processing unit), which encourages them to increase their visibility through digitalization and sustainability through green-related changes.

Nevertheless, green and digital changes are combined in the following years. This can be attributed to the fact that there have been several funding programs that supported these changes (e.g. the visitable winery used one program to upgrade their website and other ones for green changes such as the photovoltaics). Therefore, coupling of digitalization and greening occurs in projects where national and international funding programs require this. However, the co-occurence of these changes can also be attributed to traceability requirements of the Green Deal (Farm to Fork strategy) and the Common Agricultural Policy (CAP) that pushed for both digitization and green changes.

RQ2: How are upskilling and reskilling initiatives developing in the context of the Twin Transition?

Figure 7: Transition Topology depicting institutional changes related to skill (and non-skill)-related initiatives as well as transition type across multiple spatial scales in the food sector in Crete, Greece (2001-2025).

In the topology (Figure 7) of the food case in Crete there are two types of patterns visible in the topology. Before 2015, skilling initiatives are absent (pattern c). From 2015 onwards, a few skilling initiatives occur at the regional and national level, coinciding with the uptake of the digital and green transition (pattern d).

Description of the Patterns, Sequences and the underlying Micro-Dynamics in the Empirical Case

The first skilling change we noted happens in 2015, when the Hellenic Mediterranean University started integrating digital skills certifications and waste management courses in the University Curricula (Event 20). Around the same period, interviewees observed a gradual institutional shift in Master's Thesis' Topics, with students choosing Innovation and green/digital transition related subjects more often (Interview05). This indicates that there might be some market shifts towards this direction. In 2018, EU co-financed three-year operational programme supporting recognised olive oil producer organizations in Greece which included training of producers (Event 25). This enabled a series of training programmes by the Olive Oil Producer Organisations (OEF), namely a Soil Analysis seminar, an Olive oil chemical analysis Organoleptic (tasting) seminar and a Pest management education seminar (Event 27, Interview05).

Later, during the pandemic, many processes were digitalized, so many employees needed to acquire digital skills. Nevertheless, no skilling programmes took place to complete this goal. From the interviews we assumed that this type of reskilling had to be done individually. Around the same time (2021-2022), two research programs were initiated by MAICh, some of which included some kind of training towards producers. These were the Interreg Project "EcovineGOALS", whose focus was the Agroecological Transition of Vineyards and which worked with organized winemakers' networks, facilitating adoption of more sustainable viticulture practices (Event 40), and the Horizon Project "ChameLEON", which was a Drone-based Livestock Monitoring Pilot, where one farmer adopted drone-based monitoring to locate animals and detect disease early (Event 44). Moreover, the MAICh Business Economics Curriculum was reformed and a sustainability and circular economy course was introduced (Event 41).

Analysis of the Dynamics of Skilling Initiatives

As already mentioned, skilling initiatives emerged much later than the first green changes in the food sector. The increase of changes at the regional level with regards to greening and digitalization (see RQ1), coincided with the first regional skilling related events, reflected in curriculum changes at higher education institutions. Skilling initiatives appear to have been

organized mainly by HEIs or funded research and operational programs rather than directly organized through companies or industry associations (with one exception). Further, this research driven focus of the existing skilling initiatives means that the immediate upskilling needs are not systematically addressed. With regards to digital skills, the pandemic increased the demand for digital skills, however no specific skill-related changes corresponding to this demand are documented. This might be associated with the structure of the food sector in Crete which is characterized by SMEs, which face barriers in regard to training their workforce.

However, a shift in the mentality of the agri-food sector since late 2010s has occured, since actors actively participate in research programs and they want to improve their practices with regards to the twin transition. Notably, there is a reliance on externally funded skilling responses in the food sector in Crete, highlighting the dependency on unstable funding cycles.

b. Transportation Sector

The Transportation Sector is the focus of three case studies by the partners HVL, FHNW and UoC. The updated data basis for the results of each case is summarized below (Table 2):

Table 2: Data basis for Task 4.2 in the Transportation Sector

HVL	FHNW	UoC
20 stakeholder interviews - Public transport firm - Logistic firm - Association - Public authorities (5) - Policy maker (2) - Academica (5)	9 stakeholder interviews - Logistic firm (3) - Cluster organisation - Public authority - VET provider	4 stakeholder interviews - Public transport firm (3) - Association
Document analysis	Document analysis	Document analysis

i. Vestland (HVL)

RQ1: To what extent is a Twin Transition emerging at the regional level within the institutional context of the labour market?

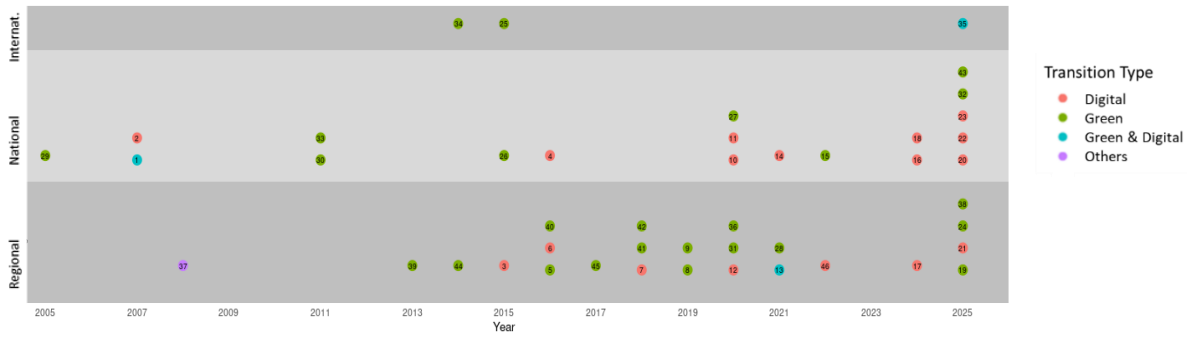

Figure 8: Transition Topology depicting institutional changes related to greening and digitalisation across multiple spatial scales in the transportation sector in Vestland, Norway (2005-2025).

The topology (Figure 8) of the transportation case in Vestland shows a trend of parallel green and digital transitions, with events covering a period of 20 years spanning between 2005 and 2025.

Initially, there was a high intensity of greening events from 2013 to 2020 (pattern a), while digitalisation gradually picks up speed from 2015, but with greater intensity from 2020 to 2025 (pattern b). The two patterns evolve largely separately with minimal integration. Most of the green transition-related events are at the regional level, while the digital transition has a higher share of national-level events.

Description of the Patterns, Sequences and the underlying Micro-Dynamics in the Empirical Case

The transport case in Vestland registers various green and digital changes at the institutional or organizational level and which were initiated by a mix of actor constellations such as regional and national firms, regional county and municipality, local universities and national government. While the green transition in transportation in Vestland was driven by a combination of policy drivers and mega projects, digitalisation has been a long-term process, more closely linked to business needs. Public and private actors play a proactive role in both processes.

The ambitious climate plan for Hordaland county in 2014 (Event 44) reflects the political priorities during the first period, which also came with high levels of (national) public support to development and implementation of green transportation technologies. This is mirrored by the environmental strategy of the public transport company (Event 39, Interview15), Bergen Municipality's green strategy (Event 5; Interview06), and the climate-ambitious regional transportation plan published in 2017 (Event 45; Interview15). Emission reductions were included in public tender criteria for ferries in 2016 (Event 40) and for busses in 2018 (Event 42). This contributed to a rapid transition of ferries from fossil fuels to electricity or hydrogen, where regional industry actors also played an active role in developing new technologies. The high level of policy ambition also contributed to the implementation of shore power and a new environmental pricing scheme at the Port of Bergen (Events 8 and 9; Interview06), which partially came as a response to the city's green strategy (Event 5; Interview06). Those regional policy driven processes were reinforced by national regulations of Shipping Act (Event 15) that introduced stricter standards for shipping companies from 2026 onwards. Furthermore, another national regulation on CCS (Event 26) and large-scale national investments through megaprojects such as the Longship (Event 27) and the Northern lights (Event 28) that necessitate sustainable and green transportation of carbon captured and the equipment provided momentum to greening of the regional transport industry.

In those greening efforts, the main actor incentivizing, coordinating and shaping the process was the Norwegian Government working in close collaboration with the maritime and ocean technology clusters, both of which are located in Vestland. While electrification of ships and ferries are still moving forward with moderate speed and significant progress, especially for short distances, hydrogen use in vessels has not achieved similar diffusion. This is because electrification of ships, despite its challenges with size of batteries for long distances, has a conducive institutional and policy environment supported by Norwegian Government. Hydrogen use in shipping however has not yet received the same degree of support and resource commitment and is facing profitability challenges.

While the highest density of digitalization related events was observed from 2020, digitalization has been going on for a longer time. For instance, desk research showed that the first digital ticket app for public transport in Vestland was introduced in 2013 (Event 46), while Posten Bring started testing self-driving mail and parcel robots in 2018 (Event 7). The digitalisation of transport in Vestland has intensified in recent years, driven by a combination of new expectations from users, technological developments in robotics and AI, new technological and business opportunities, and active use of national knowledge networks through Kollektivtrafikkforeningen (association of

public transport companies). To illustrate, the networks established through this association eventually materialised into a new organisational form where Skyss shares IT-operations with the public transport company of Oslo through the co-owned IT-company TET Digital (Event 16; Interview02). This organisational development is presented mainly as a strengthening of the digital skill-base, rather than a saving measure. Moreover, Posten Bring, as a national mail delivery company, which has one of its bases and a substantial amount of business operations in the region, digitalized its business operations heavily starting with testing self-driving mail and parcel robots in 2018 (Event 7), followed by self-driving trucks in 2021 (Event 14) and use of augmented AI in 2025 (Event 21; Interview09).

International stakeholders in both the private and public sectors exert influence primarily through flagship megaprojects such as Longship or Northern Lights, or regulations such as the EU Directive on CCS operation (Event 25) which has shaped national regulations. Some of those global players are Heidelberg Materials, Shell, Total Energies and European Commission. Their involvement is in the green transition process of the regional transport industry.

Analysis of the Twin Transition Dynamics

Whereas regional and national policy and large-scale investments via megaprojects were a strong driver of greening, digitalisation is largely led by firms supported by local universities. Some greening related changes at the regional level have strong support and resource allocation from the government while digital transition efforts of a national firm in Vestland is more advanced in comparison to other branches. Therefore, greening was driven more by regulatory developments in particular in the public transport sector. Digitalisation in logistics is mostly driven by efficiency and technological advancements in the sector rather than regionally coordination.

The overlap between greening and digitalisation is rather limited and mostly indirect. For instance, digitalisation can be used for optimisation, and thus reduce the energy consumption in public transport and logistics in public transport, digitalisation improves the user-experience and facilitates use of public transport. Since public transport is a greener alternative to many other modes of transport, digitalisation can thus be seen as contributing to greening.

RQ2: How are upskilling and reskilling initiatives developing in the context of the Twin Transition?

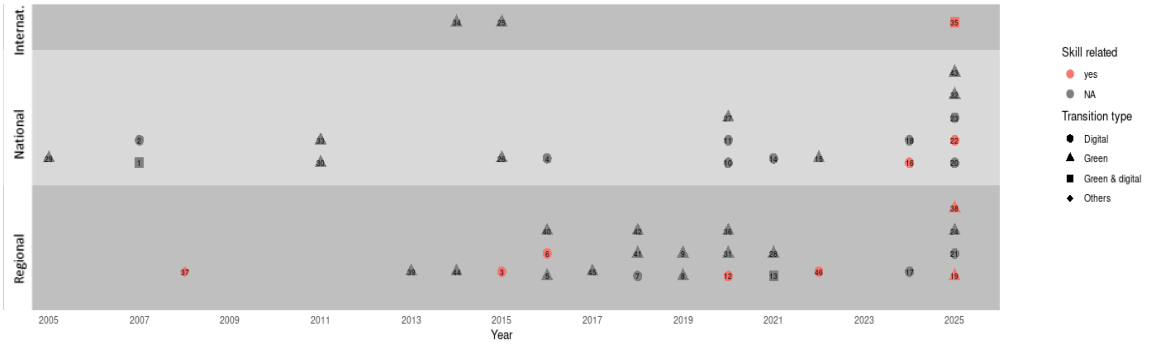

Figure 9: Transition Topology depicting institutional changes related to skill (and non-skill)-related initiatives as well as actor groups across multiple spatial scales in the transportation sector in Vestland, Norway (2005-2025).

The topology (Figure 9) of the transport case in Vestland shows that first skilling events emerged as early as 2008 within the green transition (pattern a) while green and digital skill initiatives develop simultaneously since throughout 2010s. From 2019 onwards, digital skilling initiatives become slightly more prominent at the same time Covid-19 takes place. The initiatives largely

follow a reactive trend emerging either as a response to major institutional changes or following the regional and firm-level organizational commitment to twin transition in the sector.

Description of the Patterns, Sequences and the underlying Micro-Dynamics in the Empirical Case

The earliest skilling initiative, Trainee Vest, was developed in 2008 (Event 37; Interview18) by the Bergen Chamber of Commerce in close collaboration with local universities and firms. The motivation behind this initiative was to address talent migration challenge from Bergen and rest of the region to Oslo. The program aimed to keep talented graduates needed by the firms within the region. While in its early years, the initiative mainly targeted green transition, digital skills have rapidly been added to the focus thanks to technological developments in early 2010s. From mid-2010s onwards, digital skills related initiatives gained momentum. HVL's one year program in business logistics (Event 6; Interview08) was introduced due to the growing significance of the logistics sector for the region and the digital restructuring it underwent. The driver behind this event was the increasing skill demand for specialized competence in complex and digitalizing supply chains, frequently articulated by regional business leaders at the time. During the same period Posten Bring established a scholarship program to its employees to encourage studying a relevant bachelor, master or one year degree programs (Event 3; Interview09) with a primarily digital skill focus. It was after 2021 following Covid-19 and increased use of digital tools by the regional and national firms that the course offered by HVL started to embed data analytics, various digital softwares into the curriculum and began collaborating with academics from UiB to adapt. Similarly, Posten Bring started a process of restructuring and strategy development for reskilling and upskilling only after some significant organizational changes regarding digitalization of services and business operations were successful resulting in digital skill needs and labour shortages (Interview09). The University of Bergen, further began supporting the logistics sector in the region with various data analytics softwares and artificial intelligence through its UIBAI platform that was established in 2022 (Event 46; Interview10).

The main skilling-initiative in public transport, which is thematic groups within Kollektivtrafikkforeningen (Event 1), has also developed a strong digital focus. The foras for knowledge exchange between public transport firms in different regions were for instance central in sharing knowledge about green criteria in transport procurement contracts. Here, Vestland was leading in green ferries, while they learned from others for electrifying the bus fleet. These fora develop quite at the pace of greening and technological change processes as the leading regional transport firms shared their knowledge with others. Yet, the sector experiences some recurring skill challenges, especially in the digital field. The founding of TET-digital (Event 17; Interview01) is a skill-related initiative – not because it provides training in a traditional sense, but because it provides a working milieu that is attractive and stimulating for those working with digitalisation of public transport. These dynamics suggest that digital transition has been unfolding more rapidly in the region compared to green transition that the regional actors have responded with these initiatives early on and adapted those initiatives in line with digital technological evolution. This fits into the overall pattern where skilling is more responsive than proactive.

In the green skilling field, an important initiative in preparation is establishment of a shared system for equipment and skills in Øygarden (Event 38; Interview07) to encourage cross-employee learning (in addition to sharing limited skilled employees) between local firms some of which cannot afford to have their own reskilling and upskilling schemes. Nonetheless, this initiative is also expected to gain momentum after the port in Øygarden is completed, pointing out institutional change precedence over skilling initiatives.

Analysis of the Dynamics of Skilling Initiatives

Skilling initiatives in Vestland's transport sector emerge responsively, mainly focusing on digital skills. The majority of digital skilling initiatives were triggered by technological developments and external shocks as Covid-19. For instance, advances in robotics and artificial intelligence results in a flourishing of digital software which requires training so that they can be fully incorporated in business operations. Covid-19 was a disruptive shock which led to a reconsideration of supply chains and digitalizing the management and fostering digital competences for restructuring. Hence, skilling initiatives tended to focus more on the logistics sector than on the public transportation sector. Digital skill initiatives were driven by firm internal restructuring and university responsiveness to industry's requirements. While these skilling activities were largely not developed collaboratively, they are marked by a joint direction. The only exception for a skilling event anticipating skill demand was the foundation of Trainee Vest in 2008.

Skilling initiatives focused on greening are few, despite the greening trajectory described under RQ1. In contrast to digital skilling, skilling related to greening emerged primarily through collective knowledge exchange mechanisms, which highlights existing barriers for SMEs to provide skilling.

ii. Northwestern Switzerland (FHNW)

RQ1: To what extent is a Twin Transition emerging at the regional level within the institutional context of the labour market?

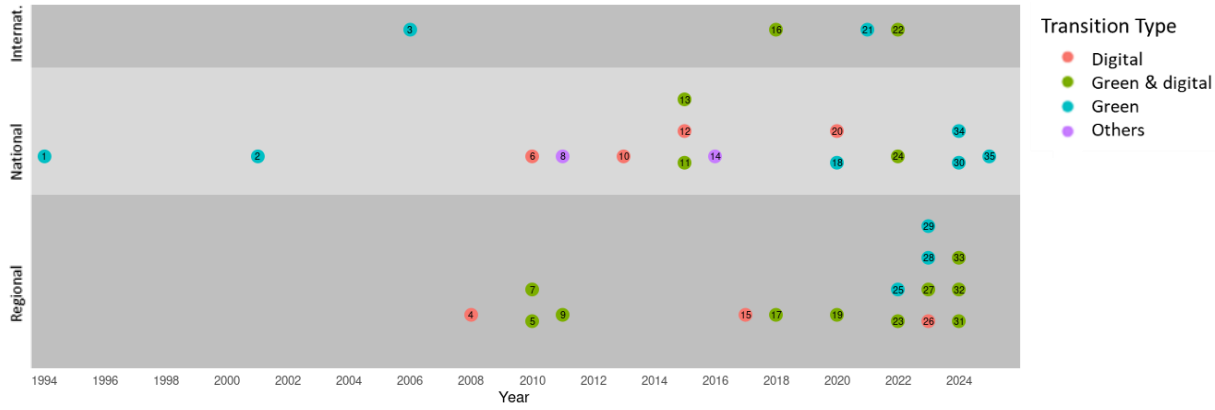

Figure 10: Transition Topology depicting institutional changes related to greening and digitalisation across multiple spatial scales in the transportation sector in Northwestern Switzerland, Switzerland (1994-2025).

In the freight transportation case in Northwestern Switzerland, as shown in the topology (Figure 10), greening-related changes clearly dominate at first (pattern a), particularly at the national and international levels during the period from 1994 to 2007. From around 2008 onwards, however, a differentiation of this pattern can be observed: alongside ongoing greening-related developments, digitalisation-related changes begin to emerge at the regional level (pattern c), with the two processes developing predominantly along separate tracks. From around 2017 onwards, a small number of changes that integrate both processes also become visible (pattern d), most notably in the inland waterway segment of the trimodal freight system.

Description of the Patterns, Sequences and the underlying Micro-Dynamics in the Empirical Case

In the freight transportation case in Northwestern Switzerland, numerous institutional and organisational changes related to greening and digitalisation can be observed over time, involving

different actor constellations across federal, cantonal, and regional governance levels and across the three transport modes that constitute the regional trimodal freight system.

Desk research and interviews show that early greening-related developments at the supra-regional level date back to the 1990s, when the Swiss popular initiative "To protect the Alpine region from transit traffic" was adopted in 1994 (Event 1). The initiative, driven by civil society and anchored in the federal constitution, mandated that transalpine freight transit must be conducted by rail and set in motion a long sequence of regulatory and infrastructural changes. Following extensive negotiations with the European Union, this constitutional obligation materialised in 2001 with the introduction of the performance-related heavy vehicle fee (LSVA) for road freight transport (Event 2; Interview02), which directly resulted from Event 1 and constituted a central regulatory instrument for shifting heavy goods traffic from road to rail. The Basel Declaration (Event 3), which promoted sustainable and low-emission shipping on the Rhine, complemented these developments in the inland waterway segment. These early greening-related events were primarily driven by civil society initiatives and federal regulatory action, with limited direct involvement of regional actors.

From 2008 onwards, the trajectory of institutional change differentiated and shifted increasingly to the regional level. A key milestone was the establishment of the Basel Region Logistics Cluster in 2008 (Event 9; Interview02), which brought together regional firms, public actors, and education and research organisations such as the University of Applied Sciences Northwestern Switzerland to coordinate innovation, training, sustainability, and digitisation in the logistics sector. The cluster represented the first substantial regional platform through which digitalisation-related concerns entered the institutional landscape of the freight sector, primarily through efforts to digitise the management of goods flows and logistics chains. This was a response to a widely recognised gap in the sector: as one sustainability manager at a regional logistics infrastructure described it, prior to such initiatives a great deal was "still done manually; things are recorded twice or three times; there is an enormous amount of work involved, and yet, in the end, the work isn't really tangible because some data is stored in one place and other data in another" (Interview05). The cluster thus provided an institutional home for the coordinated push to address these inefficiencies. In a similar vein, tertiary continuing education programmes in digital and sustainable supply chains were introduced at the regional level (Event 7), driven primarily by academic actors.

Between 2011 and 2017, regional development paused, while national-level activity continued. SBB Cargo International AG was founded (Event 8), and specialised training programmes in rail transport were introduced (Event 13), reflecting the continued importance of the federal level in shaping the rail-based dimension of the freight system. These developments were primarily driven by business-sector actors, sometimes in collaboration with public authorities.
From 2017 onwards, regional development resumed and was accompanied by relevant events at the national and international levels. The Mannheim Declaration (Event 16) on sustainable and digital shipping on the Rhine marked an important moment in which greening- and digitalisation-related agendas became explicitly linked within the inland waterway segment, reflecting the international governance structures of Rhine shipping. At the cantonal level, the popular initiative for a climate-neutral Basel-Stadt by 2037 (Event 25) added regulatory pressure for decarbonisation, while the federal tightening of the LSVA (Event 34; Interview04) further reinforced the green trajectory at the national level. Practitioners in the road freight segment confirm the LSVA's direct effect on fleet decisions. As one road freight operator explained: "when it comes to e-mobility [...] it is not only customers who are driving this development. It is also currently a cost factor or a cost advantage. This is because electric trucks are exempt from the

LSVA for companies" (Interview04). The pace of institutional change in both transitions accelerated noticeably following the COVID-19 pandemic.
In terms of governance and funding structures, a clear pattern can be observed: greening-related changes were predominantly initiated and funded through federal and international regulatory instruments and civil society initiatives, while digitalisation-related changes relied more strongly on regional cluster activity, academic actors, and business-sector initiatives, with comparatively limited federal regulatory involvement.

Analysis of the Twin Transition Dynamics

The case shows that greening and digitalisation followed distinct and, for a long time, largely unconnected development logics in the Northwestern Swiss freight transportation sector. Greening evolved as a regulation-driven and largely top-down process, anchored in civil society popular initiatives at the federal and cantonal levels and translated into binding instruments such as the LSVA and the cantonal net-zero target. Its drivers were civil society mobilisation, constitutional and federal regulation, and international agreements, with regional actors primarily acting as implementers rather than initiators. In contrast, digitalisation developed as a more bottom-up, regionally and business-driven process, organised through the Basel Region Logistics Cluster and academic actors at the University of Applied Sciences Northwestern Switzerland, and shaped by sectoral demands for more efficient logistics chains rather than by binding regulation.

The interaction between these trajectories was facilitated above all by the Basel Region Logistics Cluster, which acted as a bridging actor by linking digitalisation, training, and sustainability concerns within a single regional platform. Concretely, the cluster's bridging function operated across three dimensions. First, it served as an organisational bridge between heterogeneous actor groups, bringing firms, public authorities, and academic institutions into regular structured contact, thereby lowering the coordination costs that had previously kept regional actors from acting collectively. Second, it functioned as a thematic bridge between the green and digital agendas, embedding both within a shared cluster mission rather than treating them as separate policy tracks. Third, it acted as a spatial bridge between supra-regional impulses and regional implementation, translating national and international regulatory changes into concrete regional innovation and training activities. This intermediary role was explicitly recognised by practitioners in the sector. A further coupling moment can be seen in the Mannheim Declaration, in which the international governance regime for Rhine shipping explicitly combined sustainability and digitalisation agendas, illustrating how the trimodal nature of freight transport can produce sector-specific integrative dynamics.

However, this integration remained partial. The asymmetry between a strongly regulated, top-down greening trajectory and a more loosely coordinated, bottom-up digitalisation trajectory persists, and the limited number of skill-related and integrative events at the regional level suggests that the operational character of much of the work in freight transport, in particular truck driving, dampens the pressure for fully integrated institutional change. This fragmentation is also visible at the operational level, where sector actors describe an absence of shared digital standards and coordination mechanisms. This absence of interoperability constrains the scope for integrated twin-transition governance and reinforces the essentially fragmented, actor-by-actor logic of change observed in the region.

In summary, the Transition Topology reveals that the Twin Transition in the freight transportation sector of Northwestern Switzerland has not emerged as a fully integrated process at the regional level, but rather as a sequential and asymmetrical process in which greening predominates in

regulatory terms, digitalisation develops in parallel through regional and business-sector channels, and integration occurs only in selected segments, most clearly in inland waterway transport.

RQ2: How are upskilling and reskilling initiatives developing in the context of the Twin Transition?

Figure 11: Transition Topology depicting institutional changes related to skill (and non-skill)-related initiatives as well as transition types across multiple spatial scales in the transportation sector in Northwestern Switzerland, Switzerland (1994-2025).

In the topology (Figure 11) of the freight transportation case in Northwestern Switzerland, skilling initiatives develop predominantly in parallel with the broader twin transition (pattern d). The vast majority of skill-related events are concentrated in the period between 2010 and 2020, while greening-related institutional changes had already begun in the 1990s and digitalisation-related changes from 2008 onwards. Skill-related events thus do not clearly precede the transition, do not emerge only in its wake, and are not entirely absent, but rather accompany it, while remaining numerically limited compared to the dominant non-skill-related events.

Description of the Patterns, Sequences and the underlying Micro-Dynamics in the Empirical Case

Skilling initiatives in the Northwestern Swiss freight transportation sector are concentrated in the decade between 2010 and 2020 and are clearly differentiated by spatial level and actor constellation.

At the regional level, two key initiatives stand out. The introduction of tertiary continuing education programmes in digital and sustainable supply chains (Event 7) represents an explicitly twin-oriented response, addressing both greening- and digitalisation-related skill needs within a single curricular framework. As one programme director (Interview09) at the institution explained, the integration of digital and sustainability content into continuing education was an ongoing priority: “Whenever I revise a programme, the question always arises as to how the topics of sustainability and digitalisation can be integrated” . The establishment of the Basel Region Logistics Cluster in 2008 (Event 9, Interview02) embedded training within a broader cluster mission that also encompassed innovation, sustainability, and digitisation, thereby tying skill development closely to the cluster’s wider sectoral coordination role. Both initiatives were primarily academia-driven .

At the national level, skilling initiatives followed a different logic and involved different actors. SBB Cargo International AG introduced specialised training programmes in rail transport (Event 13; Interview09), and the national professional association SpedLogSwiss developed initiatives to train qualified personnel for the logistics and freight forwarding sector (Event 14; Interview01). These initiatives were primarily business-sector driven, in some cases in collaboration with the public sector (notably in Events 12 and 13) and were tied to the national vocational training and

dual education system that characterises the Swiss institutional context. They responded primarily to sectoral and operational requirements rather than to an explicit twin-transition framing. Alongside formalised training, companies also took informal measures to manage the pace of technological change, notably by pairing younger and older employees. One rail freight operator (Interview06) described this approach: “we encourage younger staff to support their more senior colleagues – so we try to set up these kinds of pairs” . This peer-learning model illustrates how firm-level responses to skilling gaps can operate in the interstices of formal training provision, complementing rather than replacing institutionalised programmes.

The temporal pattern of parallel rather than anticipatory or reactive skilling can be explained by several mechanisms. First, the dominant greening trajectory, anchored in federal and constitutional instruments such as the modal-shift mandate and the LSVA, primarily targeted infrastructure and regulation rather than the transformation of job profiles, which limited the immediate pressure for new skill formation. Second, the operational character of many roles in freight transport, in particular truck driving, was not fundamentally altered by the green and digital changes affecting the sector, dampening the need for large-scale reskilling. Third, the Swiss system of vocational and dual education provided an existing institutional infrastructure into which new skill needs could be incorporated incrementally, through targeted continuing education programmes and association-led initiatives, rather than through a wholesale reorganisation of training provision. Civil society involvement in skill questions was indirect and channelled primarily through popular initiatives at both national and regional levels rather than through direct skilling activity. Where digitalisation did reduce staffing requirements, this tended to happen through natural attrition and internal redeployment rather than formal reskilling. One road freight manager (Interview04) described the human consequences of process digitalisation directly: “people have also begun to realise this – suddenly they have nothing to do, they finish work earlier and no longer reach their target hours – that meant I had to start hiring people from my team internally to other departments. I had to retrain people”. This account illustrates how firm-level adaptation to digitalisation often bypassed formal skilling channels, relying instead on ad-hoc redeployment within existing workforces.

Differences between greening- and digitalisation-related skilling logics are also visible. Digital skilling at the regional level was carried by academic actors and the Basel Region Logistics Cluster and addressed the integration of digital and sustainable supply chain management. Greening-related skilling, by contrast, was less prominent as a stand-alone initiative and was more often embedded within wider sectoral training programmes at the national level, reflecting the regulatory rather than skill-centred character of the greening trajectory in this sector.

Analysis of the Dynamics of Skilling Initiatives

The case shows that skilling initiatives in the Northwestern Swiss freight transportation sector emerged largely in parallel with the broader twin transition, but on a comparatively modest scale. Their main drivers at the regional level were academic actors and the Basel Region Logistics Cluster, which translated the broader twin agenda into concrete continuing education formats, while at the national level business-sector actors and professional associations developed sector-specific training programmes within the established vocational and dual education system.

The main barriers to a more pronounced or anticipatory skilling response were the operational stability of many freight transport roles, the dominance of regulatory and infrastructural rather than skill-centred greening instruments, and the limited integration between the greening- and digitalisation-related event streams, which reduced the pressure to develop fully integrated twin-

oriented training formats. The strong federal and international shaping of greening-related events also limited the room for regional skilling actors to anticipate institutional change rather than respond to it. A further structural barrier is the declining attractiveness of operational roles in logistics, which reduces the pool of workers requiring upskilling in the first place. This shift compounds the challenge for skilling organisations, which must prepare workers for roles that are simultaneously diminishing in volume and rising in technical complexity.

In consequence, the skilling landscape in the regional freight transportation sector remains differentiated by spatial level and actor type, with academic and cluster-based initiatives at the regional level addressing the twin-transition framing more explicitly, and business-sector initiatives at the national level continuing to operate along more traditional sectoral lines. The hypothesis suggested by the topology that the twin transition does not substantially alter job profiles within the sector, is consistent with this observed pattern of parallel but limited skilling activity.

iii. Crete (UoC)

RQ1: To what extent is a Twin Transition emerging at the regional level within the institutional context of the labour market?

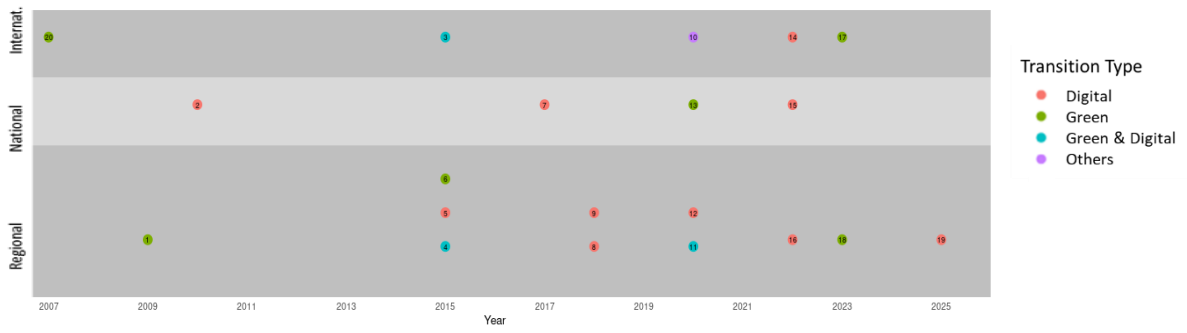

Figure 15: Transition Topology depicting institutional changes related to the greening and digitalisation across multiple spatial scales in the transportation sector in Crete, Greece (2007-2026).

For the Cretan transportation case we observe in the topology (Figure 15) that changes are more or less scattered. In the early phase, one greening-related event takes place at the regional scale (pattern a). From 2015 onwards, events increase at the regional scale, with digitalisation-related changes predominating and a few changes integrating both types of changes (pattern b and pattern d). Furthermore, there is a balance between national and international events and regional ones. This might indicate that regional changes take place as a response to national and international ones.

Description of the Patterns, Sequences and the underlying Micro-Dynamics in the Empirical Case

In the early phase of the transition topology, events are scarce and only one greening-related event takes place at the regional level. The first change that was described by interviewees was the first phase of the renewal of the KTEL Chania–Rethymno bus fleet, which took place in 2009 (Event 1; Interview02). The interviewee mentioned that this change was driven by national-level regulatory and funding frameworks related to vehicle emissions standards and environmental compliance. Around the same time (2010), there was a national reform in order to obtain a taxi driver's license in Chania, according to which taxi drivers need to pass digital literacy (among other) exams every 5 years (Event 2; Interview02).

After 2015, several changes take place at the regional scale, especially with regards to digitalisation. Taxis gradually transitioned from analogue radio systems to automated digital systems and smartphones due to marker pressure (2015) (Event 5; Interview03) and introduced POS terminals in their vehicles due to pressure by the Greek law (2017) (Event 7; Interview03). In 2020 we also see the introduction of the first electric and hybrid taxis in Chania, representing some greening related technological changes (Event 13; Interview03).

Moreover, the 2nd phase of the modernization of the bus fleet started in 2015 and finished in 2018, in order to comply with EU Regulation (EU) No 715/2007 (Event 6; Interview03). Regarding digital changes, the KTEL bus company established an internal IT/digitalization unit to support the ongoing digital transformation (Event 8), which made possible the introduction and gradual expansion of the company's website and the electronic ticketing system (Event 9; Interview02). According to the interviewee, this initiative was internally driven by the organization, particularly its IT unit, without targeted public funding, in order to comply with market needs and increase customer satisfaction. They also mention that the pandemic pushed further towards improving their digital services due to the avoidance of physical contact (Event 13, Interview02). The most recent step taken by the bus company was that since summer of 2023 ticket inspectors began using mobile devices to issue tickets and accept card payments onboard buses (Event 19; Interview02).

In the maritime transportation sector, the first twin transition change happened in 2015, when Digital Monitoring Systems for Vessel Operations were introduced (Event 4, Interview01) in response to the regulation (EU) 2015/757 that introduced mandatory monitoring, reporting and verification of CO_2 emissions for maritime transport (Event 3, Interview01). This therefore represents an event showing some integration of digitalisation and greening. Later, in 2023, according to desk research, the Directive (EU) 2023/959 amended Directive 2003/87/EC, extended the EU Emissions Trading System to maritime transport as part of the Fit for 55 package. This introduced carbon pricing obligations for shipping emissions, transforming emissions from a monitoring issue into a direct economic cost (Event 18). In response to the EU ETS extension, the company modified its routing strategy by adding Milos as an intermediate stop, leveraging exemptions for small islands under the EU emissions framework (Event 19, Interview01). In addition to this, in 2020, the maritime company shifted towards remote work due to the pandemic, which, according to the interviewee was both a digital and a green change, due to the reduction of energy consumption in the offices of the company (Event 11, Interview01). The shift towards remote worked heightened awareness of cybersecurity risks, and, thus, the Directive (EU) 2022/2555 (NIS2) mandated enhanced cybersecurity requirements for critical sectors, including transport (Event 14). Directive (EU) 2022/2555 (NIS2) mandated enhanced cybersecurity requirements for critical sectors, including transport (Event 15), which pushed the company to increase their cybersecurity measures (Event 16, Interview01).

Overall, in the transportation sector in Crete, we notice scattered changes, mostly pushed by legal obligations. Nevertheless, there were some digital changes (e.g. the website and online ticketing system from KTEL and the smartphone use by taxi drivers) that happened due to market pressure.

Analysis of the Twin Transition Dynamics

In the Cretan transport case, greening-related changes appear earlier than digitalisation-related changes, but after 2015 digitalisation dominates with few greening-related events. Where both dimensions are affected simultaneously, this occurs through regulatory coupling rather than deliberate strategy. This is the case for maritime transportation where after EU MRV regulation for

Maritime CO2 emissions was introduced, increased digitalization was required in order to monitor the environmental impact of the company. More broadly, digital changes were driven by market pressure and operational efficiency demands, while greening changes occurred primarily where mandatory driven by regulatory requirements rather than by firm initiative or ecological values. Public actors play a role in establishing regulation which is then adapted by economic actors, but proactive greening at the firm level is largely absent. Interview partners attributed this absence of a voluntary green transition in public transportation to the structural unattractiveness and unreadiness of the public transport sector in Crete relative to private cars. This reflects the need for a broader modal shift in which a green transition in the transport sector can occur.

RQ2: How are upskilling and reskilling initiatives developing in the context of the Twin Transition?

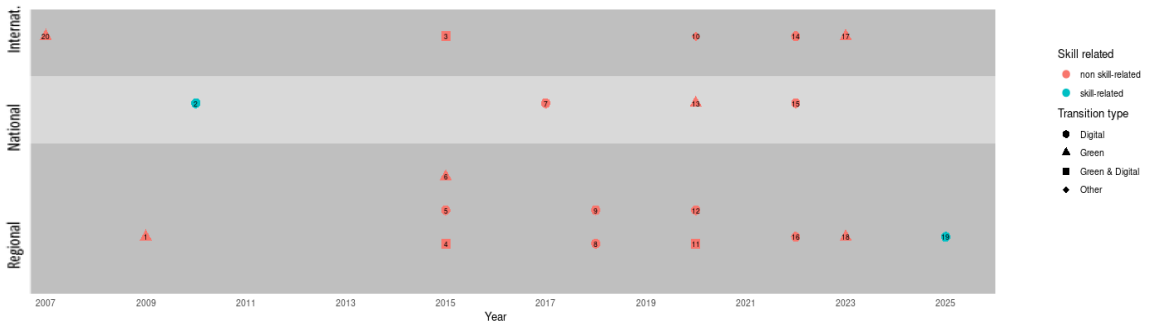

Figure 12: Transition Topology depicting institutional changes related to skill (and non-skill)-related initiatives as well as transition type across multiple spatial scales in the transportation sector in Crete, Greece (2007-2025).

Regarding the skilling initiatives in the transportation sector in the region of Crete, the topology (Figure 12) shows that skilling initiatives are almost entirely absent or very rare (pattern c).

Description of the Patterns, Sequences and the underlying Micro-Dynamics in the Empirical Case

One of the first skilling initiatives that took place was the reform of the taxi drivers' license in 2010. After the reform, taxi drivers will be examined, among other skills, on their digital literacy and they will have to take the license test every 5 years (Event 2). Later, the radio taxi was digitalised, smartphones started being used, and POS terminals became mandatory to have, but taxi drivers had to acquire the skills to use this technology on their own, (Interview01).

The local bus companies (KTEL), established an internal IT/digitalization unit in 2018 (Event 9) in order to build and maintain the website and the digital systems of the company. Nevertheless, they hired trained professionals for this initiative, so no official training took place. In 2025 ticket inspectors start using mobile devices to issue tickets and accept card payments onboard buses (Event 19, Interview02). This change required an upskilling of some members of the staff in order to adapt to this new workflow. However, the interviewees expressed that digital and green skills do not represent a problem in this sector. Interview partners emphasized the importance of social skills and the knowledge of foreign languages due to their relevance for tourism, and on medical emergency skills. Interviewees also mentioned that it is more difficult for them to find employees with manual skills (e.g., drivers and cleaners) than people with higher degrees of education.

Finally, the IT Manager of a large ferry company (Interview01), mentioned a number of digital changes that were implemented in their organization during the last years. However, the interviewee explicitly stated that no training has been required for the staff, because their workflow was not radically altered.

Analysis of the Dynamics of Skilling Initiatives

The skilling dynamic in Cretan transport is characterised by a near-absence of skilling initiatives. The few identifiable skilling-related events are compliance or operationally-driven responses implemented through internal training programs rather than being open to the larger transportation sector. The skilling-related initiatives that can be observed focus on digital skills, therefore reflecting the general transition trajectory observed for RQ1. Furthermore, employees are largely expected to obtain these skills independently.

c. Tourism Sector

The Tourism Sector is the focus of two case studies by the partners HVL and UoC. The updated data basis for the results of each case is summarized below (Table 3):

Table 3: Data basis for Task 4.2 in the Tourism Sector

HVL	UoC
9 stakeholder interviews – Private employer/firm (3) – Employer organisation – Academia – VET provider – Policy actor – Regional development organisation – Tourism organisation	9 stakeholder interviews – Private employer/firm (2) – Entrepreneur – Academia (2) – VET provider (2)
Document analysis	Document analysis

i. Vestland (HVL)

<u>RQ1: To what extent is a Twin Transition emerging at the regional level within the institutional context of the labour market?</u>

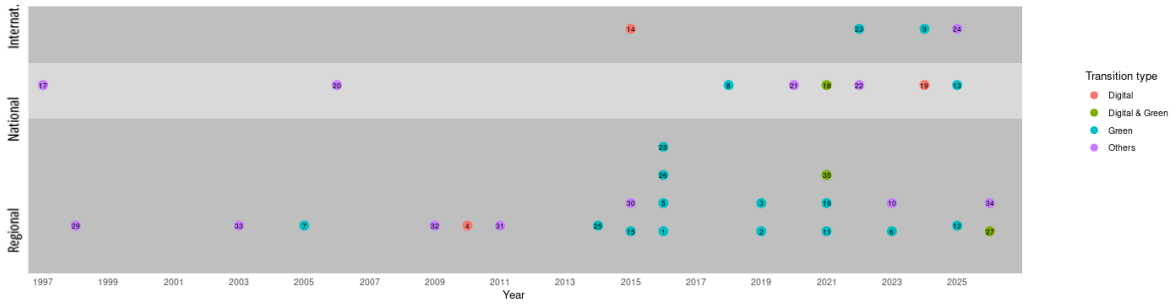

Figure 13: Transition Topology depicting institutional changes related to greening and digitalisation across multiple spatial scales in the tourism sector in Vestland, Norway (1997-2025).

As shown in the topology (Figure 13) of the tourism case in the Vestland region, Norway, greening-related events clearly predominate, corresponding to pattern (a). Greening activities are concentrated at the regional scale, particularly between 2015 and 2021. Digitalisation-related events are rare and do not form a coherent stream, but appear mainly as isolated firm-level cases or as links to national initiatives. There is no observable coupling between greening and

digitalisation events, and thus no evidence of patterns (d). Overall, the topology is best characterised as a pattern (a) configuration.

Description of the Patterns, Sequences and the underlying Micro-Dynamics in the Empirical Case

There was a concentration of greening related events from around 2015, dominated by events at the regional level, but in interaction with national and international events and actors. These include institutional and organisational changes, evolving in interaction between public and private actors across levels.

The greening processes in the tourism industry in Vestland become visible in form of three streams of events in the topology, where one is linked to the UNESCO world heritage fjords, the second is a stream of events linked to green transportation technologies, and the third is a local stream of events aimed at strengthening local food value chains by integrating these with the local tourism industry in the Sognefjord area.

With regard to the first stream, the Nærøyfjord and Geirangerfjord gained UNESCO world heritage status in 2005 (Event 7). UNESCO world heritage status as natural or landscape heritage comes with requirements of landscape- and nature protection, and areas that hold world heritage status are periodically evaluated. The process of achieving the world heritage status linked local actors – specifically mayors in the Aurland (Nærøyfjord) and Stranda (Geirangerfjord) municipalities – with national actors filing the application on behalf of Norway. In this process, the Nærøyfjord was also made a landscape protection area, creating a permanent linkage between local and regional actors in the landscape protection board – where mayors of multiple municipalities in the region, and the county mayors and county governors of Vestland and Møre og Romsdal counties are represented. The UNESCO world heritage status thus brought both institutional change, in the form of specific requirements and expectations, and organisational change which involves new actors across scales in decisions affecting local communities and tourism activity in these locations. Over the longer run, these have come to have an impact on broader greening processes (Bækkelund 2022).

From 2015 to 2025 there is a second stream of events linked to green technologies for transportation, most of which take place at the regional level, but with interaction with events and actors at the national level. These have to do with electrification of buses (Events 12, 16 and 17) and sea transport (Events 2, 3, 5, 8, 13). In the middle of the 2010s, the level of ambition regarding electrification of transport in the region was very high, both among policymakers, and private and public sector actors. As one practitioner explained: “we said to ourselves that if we want to meet the future emission requirements, then it's in transportation that we must do it. We initiated an electrifcation program where we did several things at once” (Interview01). In 2014, the Hordaland region (later merged into Vestland) published an ambitious climate plan (Event 26). Bergen Municipality published their green strategy in 2016, with the stated goal of becoming a zero-emission municipality by 2030 (Event 1). In this period, forward-looking firms started their own electrification programs – a major cruise service company started an electrification program for their busses (Event 16), and the process of developing electric sightseeing boats for the world heritage fjords is initiated in collaboration between tourism and maritime technology firms in the region (Event 5). The Port of Bergen also initiated electrification efforts, leading to shore power being implemented from 2019 (Event 2) in combination with their new, environmental pricing scheme called Environmental Port Index (Event 3).

From around 2014, there is growing debate about the environmental impact of cruise tourism, both in cruise harbors in the region, and in national media. This takes place in a period where

other transportation segments (in tourism and beyond) are rapidly greening. This was part of the motivation for the efforts at the Port of Bergen, which were described as starting from a situation with "a sort of fog or clouds hanging over Bergen city centre especially, which got a lot of attention from the politicians and media" (Interview06). In the Nærøyfjord area, which is home to the region's second largest cruise port after Bergen, a similar process was initiated, where the local port authorities in 2016 prepare for setting up shore power (Event 27). However, this comes in conflict with a national policy process, which ends up in a zero-emission requirement for cruise ships in the world heritage fjords being announced in 2018 (Event 8; Interview01). As there is no zero-emission technology for cruise ships, the local tourism industry temporarily halts any investment linked to cruise tourism – including greening technologies for cruise ships. The requirement is eventually amended. However, the process led both to strengthening the normative expectations linked to the UNESCO world heritage status of the fjords, and to more stringent regulatory frameworks. This resulted in a ban on any fossile driven passenger freight in the Nærøyfjord-branch, and a series of new environmental regulations requirements in the rest of the Aurland and Geiranger fjords (Bækkelund 2022).

The UNESCO world heritage stream and the green technology stream came to interact as the UNESCO world heritage fjords were activated in the policy process to provide an area of special jurisdiction, which some envisioned as way to create a niche for new, emission free maritime technologies. This policy initiative was launched without the knowing of local actors in the UNESCO world heritage area, unsettling some of the ongoing greening efforts in the Flåm and Nærøyfjord-area by changing the regulative landscape. Since the streams are driven by different actors with different goals and interests, and for a long time developed separately, the green technology and UNESCO world heritage streams are best understood as two separate streams that come to interact for a period from 2018 onwards.

The third stream of greening related events becoming visible in the topology is linked to increasing the use of local ingredients in the food segment of the tourism industry in Vestland. This stream is partially about greening through the use of local ingredients, and partially about economic goals linked to creating local spillovers and fostering high-quality experiences for travellers in Vestland. Over the years, the Vestland region has seen a series of events linked to promoting local produce and food traditions (Interview08&09). A pioneering event was the organisation of Smalahovesleppet at Voss in 1998 (Event 30), which is festivity evolving around a local dish from the town of Voss. In addition to the town Voss, producers in the Hardanger fjord area early organsied to promote their traditional produce. Cider producers in Hardanger organised in 2003 (Event 34) and obtained Protected Geographical Indication for their cider in 2009 (Event 33). Local food producers in the Hardanger area set up a cooperative to promote local food production and consumption, especially in restaurants, in 2011 (Event 32). The village Ulvik, in Hardanger, becomes a Cittaslow-village in 2016 – where local food traditions is among the traditions promoted as part of the slow lifestyle (Event 29). Bergen, the only city in Vestland, becomes a UNESCO Creative City of Gastronomy in 2015 (Event 32).

The Sognefjord area, despite being an agricultural region, seems to have been slower to organise for promoting their food traditions in tourism. A recent event in this area is the Sogn Mat og Drikke project, launched in 2023 (Event 10; Interview08&09). The project had the dual aim of increasing the access to chefs and food workers in the local tourism and food industries, and of securing the economic sustainability of the chef- and food technician education at Sogndal upper secondary school. The project was initiated by the firms Lerum and Norway's Best, who approached the local business development council and Sogndal upper secondary school.

In addition to Sogn Mat og Drikke, cider producers in the Sogn area have organised in recent years and obtained Protected Geographical Indication in 2026. There is an increasing degree of organisation among food producers and the HORECA segment in the region, and the constellation of actors established in the Sogn Mat og Drikke project is now involved in developing a project to strengthen local food value chains, led by Sogn business council (Event 28; Interview09). The goal of this project is to develop a model for local small-scale logistics to ease the trade of local produce from farms in the Sognefjord region to consumers, hotels and restaurants in the region. This project is aiming to tackle a common difficulty for local food value chains, and combines digitalisation and greening aspects. While the topology is dominated by greening related events, the regional tourism industry is also undergoing digitalisation. Much of this relates to firm-internal organizational changes, such as new and more advanced booking and management systems at hotels, which do not appear in the topology. However, there have been some major digital transition events in the region, as well as relevant events at the national and international scales. Norway's Best, who manage most tourism operations in the Nærøyfjord area, developed their own booking platform already in the 2010s (Event 4; Interview01). This was a proactive choice in an era where on-line travel agencies (OTAs, such as Booking.com and AirBnB) reduce the control of local actors over their own booking. In most destinations, it has now become difficult to avoid using these actors, which has reduced local actors' room for sustainable destination management (Event 15; Interview03).

The green and digital transition processes in this case have quite different drivers and dynamics. Regional and national policy goals were a strong driver for greening. However, some destinations and companies also saw this as a business opportunity. This was the case for the City of Bergen, who worked systematically to be certified as a green destination (Event 11; Interview03), the cruise service firm and Norway's Best who were early movers on green technologies, and the Port of Bergen, that developed Environmental Port Index as a separate company. Both from the policy and business side, the Vestland region has been leading in greening tourism.
While digitalisation for the most part took place as implementation of and adaptation to international trends in the industry, greening was to a larger extent driven by regional actors. Yet, although there was a strong drive towards greening both at the regional and national level, the processes at different scales were not always in synch. For instance, they came into conflict around the policies for the world heritage fjords, followed by a long process of realignment leading eventually to a new regulatory regime.

Analysis of the Twin Transition Dynamics

There is little interaction between green and digital transitions in the Vestland tourism industry. Digitalisation was first and foremost driven by business logics, where most firms digitalised for efficiency and for reaching markets in effective ways. With a few notable exceptions, most regional firms were followers to international developments in digitalising the industry.

Greening related changes were on the one hand initiated by regional and national policy goals, which were then adopted by tourism businesses and municipalities. This is especially evident with the concentration of events linked to the technological-driven greening of transportation from 2015 to 2021. However, although there was a strong drive towards greening both at the regional and national level, these processes were conflicting at times. On the other hand, greening in connection to local food tourism appears to have emerged regionally and is more value-based, initiated by local food cooperatives and municipalities.

Where the greening and digitalisation processes interact, this is only to a marginal extent. This is the case for the stream of local food tourism, where digitalisation is integrated for strengthening

regional food value chains. However, the more impactful digitalisaton trend, where online travel agents are having a larger influence on travel patterns and distribution of profits among actors in the sector, is described as having a negative impact as it reduces local actors' space for sustainable destination management.

RQ2: How are upskilling and reskilling initiatives developing in the context of the Twin Transition?

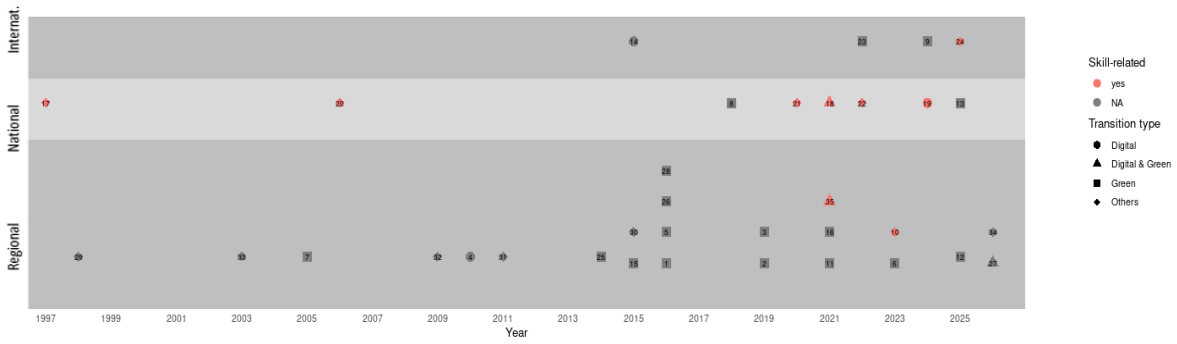

Figure 14: Transition Topology depicting institutional changes related to skill (and non-skill)-related initiatives as well as transition type across multiple spatial scales in the tourism sector in Vestland, Norway (1997-2025).

The topology (Figure 14) of the Vestland tourism industry case shows a general pattern where skilling and upskilling initiatives appear only after greening and digitalisation is well underway in the sector (pattern a). However, previous events associated with the skilling system not related to digitalisation and greening appear to have enabled the latter development of skilling and upskilling initiatives for the green and digital transitions. Most of the skilling related events take place at the national level and are initiated by private and public actors alike.

While the green and digital transitions in the case are not strongly related, the twin transition is to larger extent seen in skilling initiatives.

Description of the Patterns, Sequences and the underlying Micro-Dynamics in the Empirical Case

The skilling initiatives connected to greening and digitalisation are preceded by two events at the national level: The Association of Tourism Firms joining the Confederation of Norwegian Enterprise (NHO) in 1997 (Event 18), and the educational reform "Kunnskapsløftet" in 2006 (Event 21; Interview04). The former laid the grounds for the NHO developing a course portfolio, with a particular focus in digitalisation in tourism businesses, which was launched in 2021 (Event 19; Interview04). This was motivated by NHO as the employeer organisation seeing a need for increasing the digital skills in the sector.

"Kunnskapsløftet" (Event 21) increased the focus on green transition skills and digital skills across all educations in Norway. It was followed by a new educational reform in 2020 (Event 22), which increased the single education institution's autonomy in designing the contents of different educations. This increased the flexibility, for instance for giving educations more green or digital content, and for new forms of collaboration with the private sector (Interview04).

In parallel with the increasing digitalisation of the tourism industry, there have been multiple events aimed at increasing digital skills and knowledge in the sector. These events have taken place at the national level. In 2021, the tourism department of the Confederation of Norwegian Enterprise (NHO) launched a course portfolio (Event 19; Interview04). A large share of the courses

in the portfolio are courses in digital skills, and most are run as on-line courses. In 2024, The Norwegian School of Hotel Management goes through a restructuring, which among other things results in new course offers linked to digital marketing and digital management tools, as well as a new one-year unit of online courses focusing on digital and green transitions in tourism (Event 20). This restructuring and change towards a higher share of digital courses was partially driven by necessity due to falling student numbers in tourism education. However, it resulted in making skilling for the digital transition more accessible, also to those already working in the tourism industry. Together with NHOs course portfolio, this is part of a movement towards digitalisation of skilling. This was also observed in firms who offer in-house training, some of whom have developed digital modules over time. This digitalised training was then further developed during the Covid-19 pandemic (Event 36) and have remained in use since then (Interview04).

There is no observation of significant skilling initiatives for green and digital transitions at the regional level. One exception was the Sogn Mat og Drikke-project (Event 10; Interview01) in 2023, made possible by the event 22 and event 23. This project includes a food ambassador position whose main role is linked to recruitment of students and changing the perception of food professions, and a chef network for chefs at restaurants in the region, aimed at increasing the knowledge about local ingredients among chefs who come from other countries and regions. The projects' dual aim of increasing the availability of qualified chefs and of increasing the knowledge about local ingredients among chefs in the region makes it somewhat unique, even though the former is a common challenge in the tourism industry and the latter is a far from new aim in the broader Vestland region.

In higher education, Nordic and European funding schemes have also been important in fostering projects for green tourism research and education (such as Event 23 and 24; Interview04&05).

Analysis of the Dynamics of Skilling Initiatives

In the case of the tourism industry in Vestland, concrete upskilling and reskilling initiatives linked to the green and digital transitions are relatively scarce. Green and digital content in regular education have gradually increased over time. However, there are some new initiatives and specific changes in education initiatives linked to the digital transition. These skilling initiatives partially are driven by a perceived need by the industry and industry analysts at the national level, and partially by higher education institution's efforts to adapt to industry needs, both when it comes to contents and modes of education.

While less visible in the regional trajectory (RQ1), the twin transition is more relevant with regards to skilling, both in course portfolios combing green and digital content, and through digital modes of education and training. These skilling initiatives relate to the local food tourism events described in RQ1.

If industry actors' perceived skill needs are a main driver of digital skilling initiatives, it is also a plausible barrier to new greening-oriented skilling initiatives. Some of the greening related changes in the tourism industry described in RQ1, has been done by implementing digital transportation technologies, and this relies mostly on technical skills. Relevant technical educations are shaped more by industry actors in transportation and engineering sectors than by the tourism industry and are normally considered to be outside the core of the tourism industry.

ii. Crete (UoC)

RQ1: To what extent is a Twin Transition emerging at the regional level within the institutional context of the labour market?

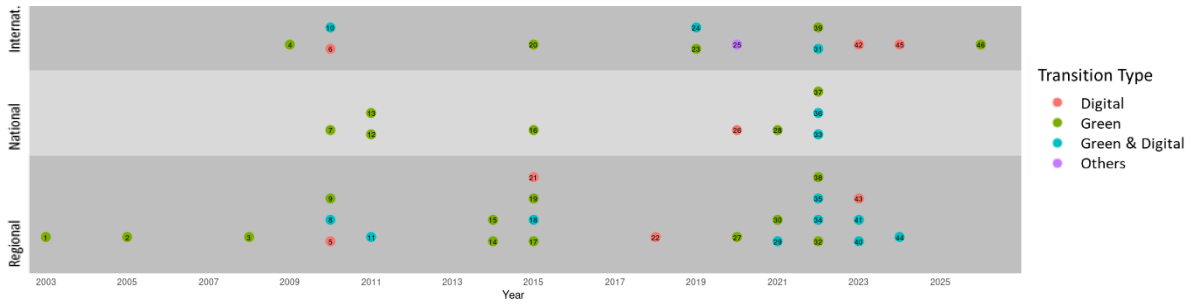

Figure 15: Transition Topology depicting institutional changes related to greening and digitalisation across multiple spatial scales in the tourism sector in Crete, Greece (2003-2025).

In the topology (Figure 15) of the tourism case in the region of Crete, three patterns of changes can be observed: From 2003 until 2008, greening-related changes are being observed at the regional level before national and institutional regulation (pattern a). In 2009, the first international change appears and, afterwards, there is an increase in changes at national and regional level. The majority of them are green-related, but there are a few digital and twin-related as well (pattern c). This pattern reaches a peak in 2015, when the largest number of changes is observed, but continues until 2018. From 2019 and especially after 2020 there is a large increase in twin transition changes in the international, national and regional level. At this stage, most changes observed are "twin transition" related and not either "green" or "digital" (pattern d).

In conclusion, the case reveals a temporal sequence in which greening-related developments initially prevail starting as early as 2003, while gradually digital-related changes develop in parallel, reaching a point where the green and digital changes are combined.

Description of the Patterns, Sequences and the underlying Micro-Dynamics in the Empirical Case

In the tourism case in the region of Crete, numerous institutional and organizational changes related to greening and digitization can be observed, which were actively shaped through the interactions of different actor constellations across multiple organizations and governance levels. The analysis will take place dividing the timeline into the three aforementioned patterns. Early on greening-related changes predominate in the tourism sector in Crete. The earliest change at the regional level dates back to 2003, when a private entrepreneur founded the "Botanical Garden of Crete" (Event 1; Interview09) following a devastating wildfire in the area. Furthermore, the Metaxa Hotel Group has adopted basic environmental practices, such as recycling, since 2008, before sustainability became regulated and required (Event 3; Interview08). These events demonstrate the readiness of a part of the private actors to accept and adopt the green transition and the interviewees attribute these changes to personal beliefs. For example one entrepreneur mentioned (Interview09) that "through this evolution of things (referring to the wildfire) and in the phase that humanity is going through, which had moved away from the natural environment, the idea arose to create a botanical garden so that humans, the visitor, could connect with the natural environment.", while another private employer (Interview08) said that the choice to implement slight internal changes came from "the will to do the right thing, recycling the most basic things, began. And then from there on, it started to become more conscious and there was this responsibility, the sense of responsibility from the management down".

After 2009, multiple green and digital changes took place in all levels, mainly in parallel. Regarding green changes, there was an increase in the interest about sustainability, green skills, and agrotourism, which can be represented by the construction of an amphitheatre in the Botanical

Garden where relevant events were held (Event 9; Interview09), and the creation of an off-grid, privatily owned, sustainability-focused teaching and training centre, European Sustainability Academy (ESA) was founded in Drapanos (Apokoronas, Crete) (Event 11; Interview04). In addition to this, a small accommodation owner mentioned the installment of photovoltaics on the roof of their touristic accommodation thanks to a funding programme. Around this period, a few national and international changes happened, such as the Greek photovoltaic rooftop programme (Event 13; Interview06), which enabled small producers to install photovoltaic systems, the fact that environmental approval for tourism-related public works became mandatory in Greece with the law 4014/2011 (Event 12; Interview03) and the Renewable Energy Directive by the EU in 2009 (Event 4), which resulted in the Greek Law 3851/2010 for the Acceleration of Renewable Energy Development (Event 7). These broader changes, though not relevant to all the mentioned regional initiatives, reflect a wider adoption of the twin transition and especially the green transition in Greece. A while later, in 2014 and 2015, small accommodation owners adopt sustainable standards and recycling practices (Event 20; Interview06), while more hotels start investing in sustainability. As the director of a large hotel in Crete mentions, hotel was totally renovating, in 2014 (Event 14) and the management invested in green and energy saving practices and in equipment replacement (LED lighting, heat pumps, planned photovoltaic and solar thermal systems) (Event 15; Interview07). The hotel has also adopted the ISO 14001 environmental management system. Nevertheless, the interviewee pointed out that these changes were not only driven by the will to reduce the environmental impact of the hotel, but also in order to reduce the cost of operation. We can therefore assume that, although some ethical reasons might be involved in the decisions of the hotels' management, applying sustainable solutions happens more eagerly when it is economically viable. This can be extended to the case of small accommodation owners as well, since the national funding programs enabled several of them to adopt sustainable solutions, such as the installation of solar panels in their rooftops, something they wouldn't be able to do with their own funds

During the same time (from 2010 onwards), digital changes start taking place when promotion, booking and management of bookings in small touristic accommodations started happening through the internet using platforms such as Booking and AirBnB (Event 6; Interview06), which increased their convenience and gains. As already mentioned, hotels had adopted such practices earlier than small and medium entrepreneurs and during this period they kept digitalizing their processes. Around 2018 one of the hotels mentions their full transition from locally managed IT infrastructure to cloud-based digital systems (Event 22; Interview07). In general, according to the interviewees, the digital transition happens due to scalability and efficiency reasons.

As already mentioned, after 2019 there is an increase in green, digital and twin initiatives. Regarding green changes, since 2019, there have been ESG requirements by banks and financial institutions, so companies, including hotels, are required to respond to international ESG finance frameworks (Event 24). In large hotel groups, such as Metaxa, a Sustainability Department is Founded (2022) (Event 38) indicating that companies recognizing sustainability as a strategic operational function (Interview08). Moreover, sustainability training programs in hotels have become more structured since 2020 (Event 27), including departmental procedures and systematic staff training on sustainability, energy saving, water management, and responsible food systems. It is worth mentioning that hotels recently started including sustainability in their marketing campaigns. Specifically, one private employer (Interview08) stated the following: "We work closely with marketing to promote it externally. The truth is that so far what the group does has not been spread as much as we would like to our visitors, because there is too much going on our part and what we do has not been spread enough. And now we have started to do more". This can also be seen in companies that were funded because of ethical reasons and whose focus has always been sustainability. For example, the Botanical Garden obtained the "Green Key Certification", an international eco-certificate for accommodations and other hospitality

facilities in 2022 (Event 39; Interview09), which indicates that they are also using their sustainable business practices as a marketing tool. These "green" changes have probably been affected by the European Green Deal (2019) (Event 23), that invests in innovation, clean technology, and green infrastructure and by the Corporate Sustainability Reporting Directive (2022) that pushes firms to prepare sustainability reporting aligned with GRI standards (Event 31; Interview08) and financial disclosure integration. Another push towards this direction was the Greek Climate Law (2022) (Event 37; Interview08) which introduced national climate neutrality targets, emissions reduction obligations, and adaptation measures affecting businesses including tourism operators.

Regarding the digital changes, hotels report that they encourage their employees to incorporate AI into their everyday work tasks since 2023 (Event 42; Interview07), which reflects a wider international institutional shift toward AI integration in service industries. Furthermore, a restaurant which reported to have integrated a robotic waiter to improve efficiency (2023) (Event 43), as well as Smart RATIONAL ovens to increase automation and better results (2024) (Event 45; Interview09). These changes indicate that green transition-related companies also focus on digital-related changes. These changes have probably been affected by the 2019 Covid-19 pandemic (Event 25; Interview02), which accelerated digitalization and automation across multiple sectors, including the tourists.

Importantly, the cost of sustainable changes makes it impossible for small and medium entrepreneurs to adopt them, even if they want to. Nevertheless, according to many professionals, society is still transitioning towards a wider adoption of green practices with many parts of it still denying them. Recently, hotels such as Metaxa have started including sustainability in their marketing strategies, reflecting a pressure from the market towards more sustainable businesses. This can be confirmed by many professionals, who point out that several visitors are willing to pay more to have a "sustainable vacation".

Analysis of the Twin Transition Dynamics

Overall, greening and digitalization-related changes occurred at different points in time. Specifically, green changes emerged much sooner than digital ones, but in recent years these two types of changes have been combined. The first green changes were initiated by private actors at the local level and mainly due to ethical reasons and occurred independently of international or national changes. Even though initial efforts for green changes happened due to ethical reasons, cost efficiency played a greater role in their wider acceptance by several actors in the latter phase. In contrast, digital changes were efficiently driven and widely accepted by all actors. National funding programs, EU legislation and national laws encouraged the emergence of more changes, green and digital, especially in recent years.

According to the interviews, the actors considered green and digital transformation as two distinct processes. In the tourism sector, digital changes took place naturally, due to market pressure, and it was almost mandatory. Green changes, on the other hand, initially happened due to personal reasons, with no consideration of the market or the laws. Later, large "green changes", such as the instalment of photovoltaics, were treated as investments that reduced costs. Currently this cost-efficiency trend continues, but market pressure for sustainable tourism is growing, which is probably why there is more visibility and more changes in this direction.

To conclude, even though some events can integrate both digitalisation and greening, both transitions remain mainly uncoupled. The green transition and the digital transition are two separate processes in Crete that are currently only combined in the context of green investments towards energy saving.

RQ2: How are upskilling and reskilling initiatives developing in the context of the Twin Transition?

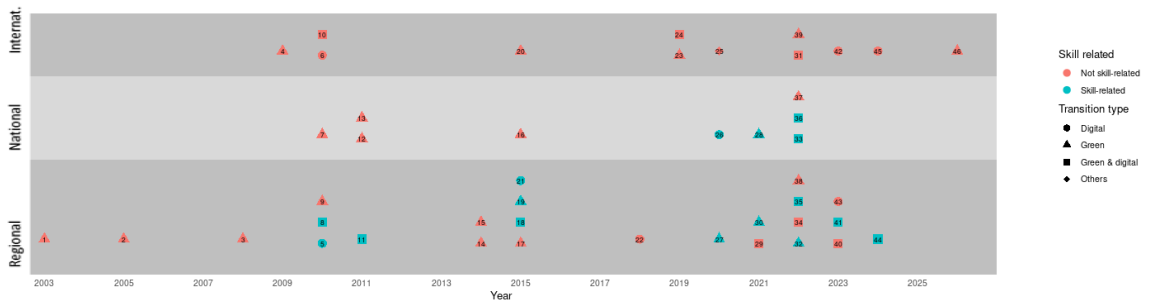

Figure 16: Transition Topology depicting institutional changes related to skill (and non-skill)-related initiatives as well as transition type across multiple spatial scales in the tourism sector in Crete, Greece (2003-2025).

As the topology (Figure 16) shows, before 2010 most changes were not skill-related; only around 2010 a few skill-related events emerge. Therefore, a pattern emerges in which skilling initiatives are almost entirely absent or very rare (pattern c). Between 2010 and 2020 skilling initiatives develop in parallel with the transition. The majority of skilling initiatives that emerge mainly focus on digital or digital and green changes at the same time (Pattern d). Then after 2020, skilling initiatives develop in parallel with the transition and become more frequent. As the focus switches to twin transition related changes overall, skill related changes also predominantly focus on both trends at the same time. In comparison to the earlier phases, green related skilling becomes more visible, indicating that skilling efforts only begin relatively late after institutional change driven by greening has already occurred (pattern a)

Description of the Patterns, Sequences and the underlying Micro-Dynamics in the Empirical Case

Before 2010, digital skills were nice to have. Around this time, regional professional associations, notably the Chania Hoteliers Association and the Pancretan Association of Hotel Managers start organizing seminars addressing digital transition skills, which indicates the necessity of such knowledge (Event 8; Interview07).

Between 2010 and 2020, a variety of skilling initiates (mainly digital- and twin transition related. Interview partners stated that around 2015 digital skills become a prerequisite for hiring by large hotel groups (Event 21; Interview08). This happens close to the transition by hotels from locally managed IT infrastructure to cloud-based digital systems (2018) (Event 22; Interview07), which explains the tendency to hire digitally skilled professionals. Green skills are not mandatory, but they are starting to be valued. This coincides with the adoption of sustainability standards by small accommodation owners (2015) (Event 20; Interview06) and with the green innovations carried out by large hotels (2014) (Events 14 & 15; Interview07). However, as mentioned in the previous RQ, sustainability is mostly about investments and cost-efficiency and not about internal processes in large hotels, so green skills are not required for the majority of employees. For small businesses, sustainability can either be an investment (photovoltaics) with the help of funding programs or a personal choice, so green skills are also only marginally affecting skills at this point.

After 2020, an increase in skill-related events takes place at both national and regional levels. According to various sources, this process of acquiring digital skills was accelerated by Covid-19. Moreover, we know that the pandemic enabled widespread adoption of online seminars and communication tools (Event 26; Interview07), which increased the digital competencies of workers even more. Currently, Metaxa hotel group collaborates with external training providers to upgrade employee digital competencies (platform use, software tools, management systems. In

addition to this, the interviewee mentions that they received technical training upon being hired, in the onboarding process. Nevertheless, we can say that new employees' basic digital skills are not just a “must have”, but also an “expected to have”. Training programs on basic skills are mostly directed to older workers.

During this period, we notice that green skills are also being considered in seminars and training courses. In 2022, a joint program took place by the Chamber of Chania, the Chamber of Rethymno, and the Technical Chamber of Crete (Event 32; Interview02), which was focused on environmental management and certification, particularly for technical works. Moreover, ΔΥΠΑ (the Public Employment Service), replaced OAED in 2022 (Event 36; Interview07) under Greek Law 4921/2022, aiming to modernize employment services, reskilling programs, and labour-market matching aligned with digital and green transitions. Since 2020, the Metaxa hotel group has been implementing Structured Sustainability Training Programs for their workers, indicating that sustainability knowledge has become part of workforce development and continuous reskilling. After 2020, we also notice a shift in academia as well. As a professor (Interview 01) informed us, a targeted academic recruitment took place in 2021 (Event 30), aimed at filling knowledge gaps related to sustainable development, tourism, entrepreneurship, marketing, and strategy. In the same year, several courses were redesigned or newly introduced, placing sustainable development at their core, especially in tourism-related teaching (Event 31; Interview08). It is worth mentioning that such shifts have probably been affected by the law 4957/2022 (Event 33) that obliges universities to adopt systematic strategic planning, creating conditions for embedding green & digital priorities, which UoC completed in 2022 utilizing an ESPA program (Event 34; Interview01). It can also be noted that UoC has participated in EU-funded Erasmus+ and Horizon projects on green and digital skills (Event 35; Interview01). In 2023, UoC expanded their staffing and further integrated digital & sustainability criteria through another ESPA program (Event 40; Interview01). A Pilot digital system for tracking indicators related to sustainable development, green practices, and digital transformation was also developed. (Event 41; Interview01) The European Sustainability Academy also coordinated and completed a 13-month Erasmus+ project focused on identifying and addressing the skills gap in the tourism sector related to the green transition (2024) (Event 44; Interview04).

However, it is necessary to mention that multiple sources claim that skills-related initiatives don’t work properly. They say either that it is insufficient or that it is done merely to show that something is being done.

Analysis of the Dynamics of Skilling Initiatives

Overall, as already mentioned in the previous RQ, green-related and digital-related upskilling programmes do not take place at the same time. The reason for that is that digital skills were more necessary for the tourism sector, so this knowledge was important to have for businesses to survive the market pressure. For green skills, on the other hand, the early greening transition at the regional level did not produce any skilling response; only later compliance and efficiency-driven greening can be linked to skilling initiatives. Therefore, skilling in the tourism case in Creta follows a broadly reactive pattern for both greening and digitalisation. Currently, there is some market pressure that encourages entrepreneurs to invest in more sustainable tourism, but, according to interview partners, Greece has not caught up with this trend, although some hotels are starting to incorporate sustainability in their marketing practices. Like in the previous RQ, it was evident that interviewees treated green-related and digital-related upskilling as two separate processes, although some programs were combining the two.

d. Energy Sector

The energy sector including cybersecurity and emerging sectors is the focus of three case studies by the partners HVL, UU and UW. The updated data basis for the results of each case is summarized below (Table 4):

Table 4: Data basis for Task 4.2 in the Energy Sector

HVL	UU	UW
18 stakeholder interviews - Academia (6) - Private firm (6) - Public authority (4)	In this case, **interviews were not included in the analysis**, as the documentary evidence provided a sufficiently rich and detailed basis for analysis within a highly institutionalised and organisationally dense context.	17 stakeholder interviews - Practitioners (6) - Innovation communities (2) - Public authority (4) - Local NGO (2) - National NGO (2) - VET (1)
Document analysis	Comprehensive document analysis	Document analysis

i. Vestland (HVL)

RQ1: To what extent is a Twin Transition emerging at the regional level within the institutional context of the labour market?

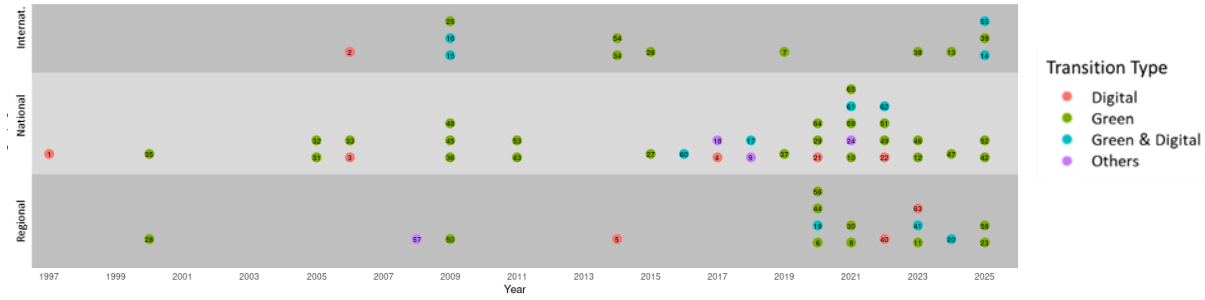

Figure 17: Transition Topology depicting institutional changes related to greening and digitalisation across multiple spatial scales in the energy sector in Vestland, Norway (2000-2025).

Based on the topology (Figure 17) of the energy case in the Vestland region, the case is best classified as pattern (a), with greening-related changes clearly dominating over the study period. At the same time, the growing number of events linking green and digital transitions from 2018 onwards points to emerging characteristics of pattern (d). Thus, while greening remains the primary driver of change, recent developments suggest an increasing integration of digital and green transformation processes.

Description of the Patterns, Sequences and the underlying Micro-Dynamics in the Empirical Case

To describe the patterns and micro-dynamics of greening and digitalisation in the energy sector in Vestland, it is necessary to shortly describe the composition of the regional energy sector. Just like the rest of Norway, hydroelectric power has been the main electricity source in Vestland since

the early 1900s. Thus, the regional electricity supply was mainly renewable based from the outset. The processes in the energy industry in Vestland can be sorted into two technological pathways, with one being the development of CCS and the other one related to renewable energies with an increasing integration into the European energy market.

As desk research shows, the greening-related pattern identified above, in the period between 2000 and 2011, involves intensive investments in green energy infrastructure which were primarily driven by the state authorities in collaboration with regional firms and multinationals. One of the earliest regional industrial activities within carbon capturing and storage was the Breivik project in 2000 (Event 28), which captures the carbon in Breivik, eastern Norway and stores it in Vestland. Equinor, SLB Capturi (a joint venture between SLB and Aker Carbon Capture) Shell, Total and Heidelberg Materials were the key players and have been collaborating in this project. It is important to note that the firm capabilities and technology development efforts within Equinor and Aker Group throughout 1990s laid the foundation for what would be a thriving CCS sector in the region. Investments in CCS infrastructure continued with the establishment of Gassnova (Event 31), a state-led (Ministry of Energy) enterprise to coordinate CCS activities, and Climit (Event 32) which is a public entity established by Norwegian Research Council in 2005 to fund CCS research and technological development activities. These were followed by investments in technology testing within CCS.

These investments in infrastructure resulted in heightened industrial activity around CCS which necessitated regulations for the sector. EU Directive on CCS safe operations (Event 26) and a similar national regulation on CCS (Event 27) was developed in 2015 to set new and update existing standards in the sector, as found in respective legal documents. The interviewees have pointed out a mutual influence between Norway and EU in regulating the CCS; initially Norwegian policymakers highly influenced EU directives on CCS throughout 2010s and more recently, the updated versions of those directives or new ones had an influence in shaping the national regulations regarding CCS in Norway. Meanwhile, large-scale investments through mega projects in CCS such as the Longship (Event 29) and The Northern Lights (Event 30; Interview09), which involved Equinor, Heidelberg Materials, Total, and Shell were made. Furthermore, private actors with support from the state founded CCUS Norge (CCS cluster) in 2025 (event 52).

With regards to broader renewable energy sectors (e.g., offshore wind), several events took place such as Technology Center Mognstad (Event 33) in 2006 and Marine Energy Test Center (Event 45) in 2009. From 2009 onwards, investments expand into other renewable energy sectors with the establishment of NORCOWE (Norwegian Center for Offshore Wind Energy) in 2009, which was funded by Norwegian Research Council and coordinated by NORCE (Event 48). In 2011, NEL was established (Event 43) as a firm in Hydro AS to produce green hydrogen. This initiative is jointly owned by the state (Ministry of Trade, Industry and Fisheries and Government Pension Fund) and other private and individual shareholders. NEL later spun out of Hydro as an independent firm in 2014. Several interviewees pointed out the drop in oil prices in 2014-2015 as an external shock that has provided some momentum in greening the energy sector, particularly in offshore wind and hydrogen. Gradual progress especially in offshore wind and hydrogen has been made between 2010-2022. To illustrate, Enova, a state enterprise (Ministry of Climate and Environment) funded the first offshore wind project in 2009 (Event 36). This event would later be registered as crucial in shifting the focus from onshore wind to feasibility of offshore wind, which indirectly provided support for onshore wind, which was already contested and did not have popular support from the Norwegian public. Between 2013-2018, public support for onshore wind was dwindling. This has resulted in freezing off onshore wind licences by the Norwegian government in 2019, while offshore wind has emerged as the other alternative that did not receive as strong opposition from the public. State support therefore continued with National Export Initiative

Offshore Wind (Event 49). These efforts have culminated in establishment of Norwegian Offshore Wind in 2021 (event 65).

Universities began playing a proactive role in renewable energy research and application. For instance, HVL established a research group on hydrogen in 2021 (event 44) while it also became part of the joint initiative HyValue with other regional universities, firms, municipality and county council (event 11; Interview02). Nevertheless, the momentum of renewable energy was interrupted by an external shock, the war in Ukraine. The war led Norway replace Russia as the main oil and gas provider to EU, which boosted sales in fossil fuels. This has stalled the pace of developments in regional renewable energy transitions, especially in offshore wind and hydrogen, as pointed out by several interviewees.

Digitalisation in the O&G industry was by one participant described as starting from the 1990s, with both firm-internal programs and national support systems for digitalisation. A significant event for digitalisation in O&G was Amazon's 'Compute in Sky' service, which was launched in 2006 (Event 2; Interview05), which laid the foundation for Equinor's 'Real time' system (Event 3; Interview05). This allowed for the use of digital twins, used among other things for predictive maintenance. O&G firms in Vestland have internal digitalisation programmes but also participate in external collaboration for digital skills through the digitalisation network Digital Norway. Digital Norway was founded in 2017 (Event 4) as a collaboration between private firms, public-private companies and the state in order to speed up digitalisation in Norwegian industries. Accordingly, the digitalisation pathway in O&G in Vestland shows a pattern of multiple drivers, where O&G firms themselves (in Vestland and neighbouring regions) are enacting strong agency, while international developments and national networks and support schemes are also contributing to driving digitalisation in the sector.

While digitalisation in O&G was a parallel development to greening linked to the sector, digitalisation in electricity production and trading has a clearer link to greening. In the electricity segment, the more significant digitalisation events are linked to the integration of the European energy markets and grids, and to the growing share of unstable renewable energy forms in the electricity mix combined with changing consumption patterns with increasing electrification of society and industry.

The first events concretizing an integration of the European energy market were the foundation of the association of the European transmission system operators, ENTSO-E, in 2009 (Event 15; Interview04) and the signing of the power purchase agreement, ACER (Event 16; Interview04). As part of the process of integration in the European electricity market, Norway joins ACER in 2018 (Event 17). In 2021, two undersea-cables connecting Norway to the UK and the EU were opened (Event 60). These cables can be used both for economic scopes and for contributing to balancing the European electricity grid. With a growing share of unstable renewable energy sources, such as wind and sun energy, grid-balancing requires a more fine-grained energy trading system. The first fully digitalised market model for electricity trading was introduced in 2025 (Event 14; Interview04). This reduced the trading-interval from one hour to 15 minutes. However, this also requires increased digitalisation in all major electricity traders in Norway – including in Western Norway.

The digitalisation of electricity trading has been driven by actors at the national and EU-level. In addition to ENTSO-E and the ACER agreement at the EU level (Events 15 and 16; Interview04), the Norwegian government funded a research centre for intelligent electricity distribution in 2016 (Event 60) and issued a white paper on the topic in 2022 (Event 62). While regional electricity producers, traders and grid-operators had the opportunity to contribute their perspectives and expertise in these processes, the largest actors in the electricity sector in Vestland appear as latecomers in this process. The main energy group in in the region only started developing new

digitalisation and digital-skill strategies in association with a major restructuring and in 2023 (Event 63).

Analysis of the Twin Transition Dynamics

Digitalisation and greening in the Vestland energy sector appear mostly as two parallel processes, which are to a little extent interconnected depending on the sub-sector. In the O&G sector, digitalisation was adopted early on by large companies, that were also driving CCS development in cooperation with national public authorities. With regards to renewable energy, it appears that greening took place before digitalization which arose as a consequence from the increasingly integrated grid. In particular, an increasing share of solar and wind energy, as well as growing and changing electricity demand (for instance the charging of EVs in households), have led to new needs for digitalisation in electricity trading. The two are driven by different logics, where digitalisation is driven largely by economic opportunity (efficiency), while greening is driven by a mix of policy drivers and economic opportunity. However, in the electricity segment, digitalisation and greening are more interlinked. In particular, an increasing share of solar and wind energy, as well as growing and changing electricity demand (for instance the charging of EVs in households), have led to digitalisation in electricity trading.

In particular three macro-level events have shaped the transition in Vestland, namely the drop in oil prices, public support for wind energy and the war in Ukraine. However, these external factors have different impact on green and digital fronts, which affects integration of the two at the regional level. For instance, the war in Ukraine has slowed down the pace of greening but it has not had a similar impact on digitalising the sector.

RQ2: How are upskilling and reskilling initiatives developing in the context of the Twin Transition?

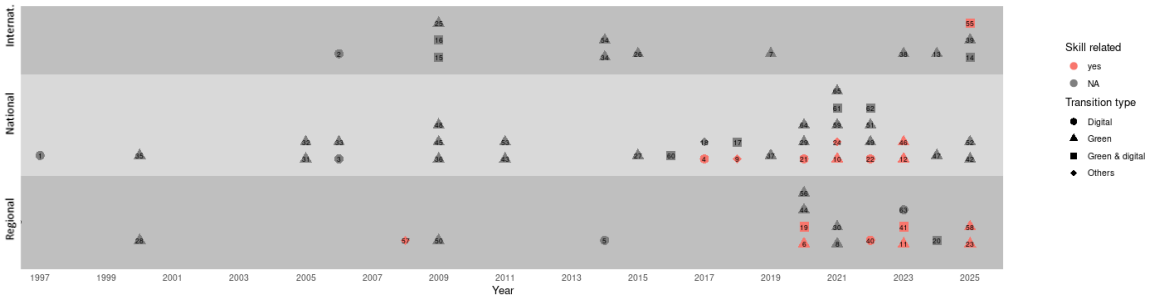

Figure 18: Transition Topology depicting institutional changes related to skill (and non-skill)-related initiatives as well as transition type across multiple spatial scales in the energy sector in Vestland, Norway (2000-2025).

The general pattern in the topology (Figure 18) for the Vestland energy sector is that the frequency of skilling initiatives, both for greening and digitalisation, at the regional as well as national level, increases from 2020 onwards (pattern d). From 2006 until 2020 only one skill-related event is depicted at the regional level (pattern c). Moreover, when looking at the micro-dynamics, there is a variation in whether skilling follows from green and digital transitions, happens in parallel or plays a proactive role. Moreover, skilling is carried out by both private and public actors.

Description of the Patterns, Sequences and the underlying Micro-Dynamics in the Empirical Case

While there was an early event related to skilling in 2008 (Event 57), the frequency of skilling events increased from 2020. Yet, the apparently higher intensity of skilling events only after greening and digitalisation was underway does not necessarily mean that skilling follows from ongoing greening and digitalisation processes. Rather, there seems to be a two-way interaction

as particularly universities have an ambition to contribute to greening independent of the speed with which green transition unfolds in industry. Regional universities have played a proactive role in addressing the supply side of skills. For instance, the Western Norway University of Applied Sciences (HVL) initiated research projects on hydrogen (Event 11) and battery technologies (Event 7), as well as introducing specialised courses linked to hydrogen (Event 6) and solar energy (Event 58; Interview01&02&08&12). Similarly, the University of Bergen (UIB) launched a package of digitalisation courses in 2021 (Event 22), independently of firm demands. UIB established UIBAI platform (Event 40) that also provides training in artificial intelligence and data analytics. Highlighting the connection to anticipated regulation the Norwegian School of Economics has established a course in Sustainability Reporting (Event 41) that is open to most students in its programs (Interview07).

On the other hand, large firms and state-sponsored networks drive appear to respond directly rto demands related to the transition in Vestland. Among the major skilling events initiated by firms is the foundation of Digital Norway (Event 4; Interview05), which represents a consolidation of the digital skills of the firms involved in developing the courses, such as Equinor, while also contributing to further digitalisation by increasing digital skills across Norwegian industries. In addition to this, there are in-house training initiatives in these larger firms, which include training in both digital and green skills. These, however, are not captured as concrete events in the topology. To contribute to increasing the access to new skills, the Bergen chamber of commerce initiated a trainee programme (Event 57), as found in desk research. This is a general programme, and includes different skill found among recent university graduates. The Norwegian Competence Center for Offshore Wind (Event 46) was established with partnership between firms and the state to coordinate the skill and training for the sector. It is financed by the state, Å Energi and Sparebanken Norge, underlining that responsive skilling initiatives appear to address digital as well as green skills

The development of new, industry- or technology specific university courses, was promoted through national funding from the Bransjeprogram, which was initiated in 2018 (Event 9; Interview02). The funds accessible through this program are always linked to specific industries or technologies, and this varies between application periods. While the program has driven new course development of relevance for instance to the development of the hydrogen sector, instable funding and unstable interest from industry actors challenges the viability of such specialised courses tailored towards fostering specific greening paths.

Analysis of the Dynamics of Skilling Initiatives

In the case of Vestland's energy sector, the drivers of skilling initiatives for greening and digitalisation appear to show two developments. First, universities and research institute contribute towards regional industry development and skill supply through developing courses and research programs in incorporating greening and digitalisation at the same time, partly influenced by regulatory changes at the European and national level. Second, large companies and networks focus on demand-side skilling by developing training with both green and digital contents. While firm-internal training is likely underdocumented in the topology, companies with similar technological interests collaborate in some areas of skilling. However, skilling initiatives by universities and public research institutions and industry skilling operate largely in parallel than in coordination. One mechanism that is directed towards coordination and specialized courses, the Bransjeprogram is characterized by instable funding.

While collaboration between firms and industry drives development of new course offers in some fields; the lack of such interaction appears to be a barrier in others. An interesting finding is that although some greening sources (e.g., hydrogen) are not yet economically viable and profitable, universities and firms continue to work towards training and skill provision in these areas. Notably

is also the absence of skilling response to CCS development evident in the energy transition of Vestland.

ii. Groot-Rijnmond (UU)

RQ1: To what extent is a Twin Transition emerging at the regional level within the institutional context of the labour market?

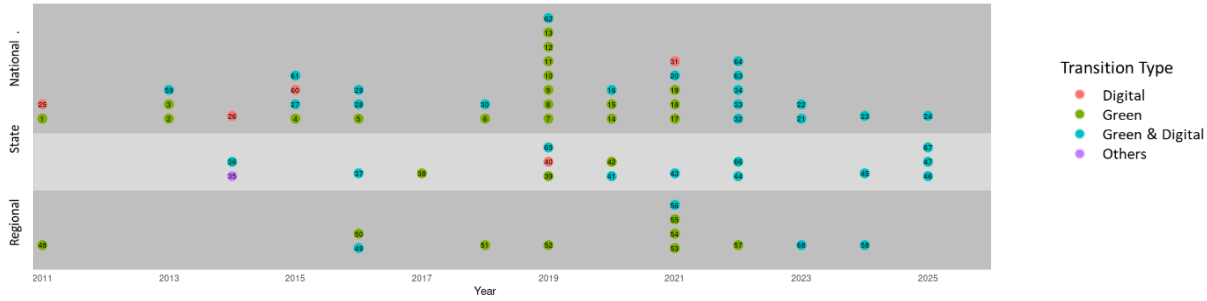

Figure 19: Transition Topology depicting institutional changes related to greening and digitalisation across multiple spatial scales in the energy sector in Groot-Rijnmond, the Netherlands (2011-2025).

The topology (Figure 19) shows that the transition of the energy sector in the Rotterdam-Rijnmond region since 2011 was predominated by greening-related changes with the majority of events taking place at the national scale (pattern a). Since 2015, digitalisation-related changes started to emerge (pattern c and pattern d) and are eventually integrated with greening-related changes in coherent manner since 2022 (pattern d). Most changes occur at the national and state-level, with a cluster of regional events occurring in 2021.

Description of the Patterns, Sequences and the underlying Micro-Dynamics in the Empirical Case

The transition of the energy sector in the Rotterdam-Rijnmond region since 2011 has gone through three main phases, which roughly correspond to the three patterns identified above.

At the national level, several climate and energy policies were adopted, including the Energy Agreement for Sustainable Development and the National Climate Agenda in 2013 (Event 2) which both highlighted the role of offshore wind energy in the energy transition, leading to the Offshore Wind Energy Act in 2015 (Event 4). The National Climate Agenda (Event 3) also set the tone for the approach of broadly-based coalitions of companies and public players). The 2016 Energy Agenda (Event 5) further extended the policy horizon toward a low-carbon energy system by 2050.

Besides the energy and climate related policies, the research and innovation policies in the Netherlands also went through significant changes during this period. In 2011, nine Top Sectors, including the Top Sector Energy (Event 1), were launched. The Top Sector Policy adopted the triple-helix model and promoted public-private partnerships in facilitating research and innovation. New organization were also created to coordinate the initiatives in each top sector.

For the Rotterdam-Rijnmond region, all these national policies strengthened the expectations of the green transition of the port-industrial complex. Particularly, the action plan of Top Sector Energy echoed the plan of the Port of Rotterdam Authority's Port Vision 2030 (Event 48) in developing the port-industrial complex into the energy hub for northwest Europe by expanding the global hub position for energy flows and through new investments in energy generation and the production of (bio)fuels. In 2016, following the national policies on offshore wind, the Rotterdam

Offshore Wind Coalition was formed (Event 50). The coalition partners include Port of Rotterdam Authority, Municipality of Rotterdam and many private actors in the Rotterdam-Rijnmond region with the ambition to build a leading offshore wind industry cluster in Europe by focusing on innovation and a sustainable society.

After the Paris Agreement in 2015, Rotterdam's green transition became more explicitly linked to industrial decarbonisation. The 2019 Dutch Climate Agreement (Event 7) was a key national turning point. It identified process efficiency, energy savings, carbon capture & storage, electrification, blue and green hydrogen, and circularity as main routes for Dutch industrial decarbonisation. Many national policy instruments and regulations were subsequently implemented in the following years, e.g. Climate Act law and Coal Phaseout law (Events 8, 10) that set up the climate and energy transition targets, the scheme Stimulating Sustainable Energy Production (SDE+) (Event 9) and Sustainable Energy Transition Scheme (SDE++) (Event 14) that supports renewable energy and CO2-reduction through subsidies, the financial schemes Multi-annual Mission-driven Innovation Program Energy Transition and Sustainability (MMIP) (Event 11) and Multi-year Programme for Energy and Climate Infrastructure (MIEK) (Event 19), and several national energy strategies including National Programme Regional Energy Strategies (RES) (Event 13), Cluster Energy Strategies (CES) (Event 18) and National Hydrogen Strategy (Event 15), etc.

During this period, the provincial government of South Holland also became more proactive in supporting the energy transition. In 2019, an Energy Transition Task Force (Event 39) was formed under the Economic Board of the province of South Holland to ensure support and facilities to accelerate the development of the Delta Grid, a strongly interconnected, CO_2 free energy system for the province of South Holland by 2050, that later was institutionalized in the Growth Agenda South Holland (Event 43) in 2021. The South Holland regional development agency InnovationQuarter also launched several investment funds to support start-ups in energy industry, e.g., UNIIQ and ENERGIIQ (Events 37, 38). The UNIIQ was co-funded by the European Regional Development Fund and focused on the proof-of-concept phase to bridge the riskiest phase from concept to promising business. The ENERGIIQ particularly financed the commercialization of proven energy innovations that leads to CO2 reduction. Over the years, both funds funded start-ups in green and digital technologies.

The municipality of Rotterdam and the Port of Rotterdam Authority were also actively involved in the regional implementation of national policies and provincial policies. In 2021, the municipality of Rotterdam launched the Rotterdam Energy Transition Fund (Event 53) that financed disruptive companies and sustainable projects that realise CO2 reduction, improvement of air quality and a reduced use of raw materials. In the same year, the Rotterdam-Den Haag Regional Energy Strategy (Event 54) was officially adopted. As the localized adaptation of the national Dutch Climate Agreement, the Rotterdam-Den Haag Regional Energy Strategy was coordinated by the Metropolitan Region Rotterdam The Hague (MRDH), in partnership with local municipalities, water boards, and grid operators. The goals further strengthened the region's role as renewable energy generation, and industrial and hydrogen hub. In 2022, the Rotterdam-Moerdijk Cluster Energy Strategy (Event 55), developed by the Rotterdam-Moerdijk Industry Cluster Work Group that included the Province of Zuid-Holland, Port of Rotterdam Authority, and many private actors, was adopted. As one of main industry cluster identified in the National Cluster Energy Strategies, the Rotterdam-Moerdijk Cluster Energy Strategy identified eight key infrastructure projects as catalysts for the regional energy transition and as important for the national economy.

During this period, the twinning between greening and digitalization started to emerge. The Digital Agenda 2016-2018 (Event 27) explicitly included the digitalisation of the energy sector as one of its core areas. The Digitalization Strategy 2018-2021 (Event 30) further strengthened the idea that

digital technology should support social challenges, including the energy transition. It also gave policy legitimacy to data sharing, digital infrastructure, AI and cybersecurity as conditions for transition governance. Also, during this period, Team Dutch Digital Delta (Event 28) was created to stimulate ICT innovation with and across Top Sectors, and later became Top Sector ICT (Event 29). Similar to other Top Sectors, Top Sector ICT identifies, prioritizes, and organizes ICT research and innovation by bringing together public and private parties, focusing on key ICT technologies and societal challenges. In doing so, the Top Sector ICT covers the trajectory from fundamental research to valorisation. Training new talent, upskilling and reskilling, knowledge dissemination, broad involvement of SMEs, and international cooperation form important components of the mission.

The most significant twinning event was the creation of the Digitalization program/agenda within the Top Sector Energy in 2021 (Event 20), which acts as a linking pin between Top Sector Energy and the Top Sector ICT, and establishes digital technology as essential infrastructure for the energy transition. It advocates for integrating IT and energy domains to move from passive consumption to a data-driven "Internet of Energy" (IoE) model that uses AI and digital twins to manage distributed, renewable-driven systems. The agenda emphasizes creating a smart energy system centred on cybersecurity, data sovereignty, and new workforce skills.

Also in 2020, the Dutch government launched the National Growth Fund to drive long-term, sustainable economic growth and secure future prosperity from 2021 (Event 16). The fund mainly supported research, development and innovation in funding fundamental research, technological scaling, and the creation of public-private innovation ecosystems, and knowledge development in investing in future-proof education, lifelong learning systems and high-tech labour skills. Several themes in the National Growth Fund are related to greening and digitalisation, such as GroenvermogenNL that aims to accelerate the green hydrogen economy and AiNed that aims to support the development and application of artificial intelligence across Dutch industries, governments and education systems.

At the provincial level, the South Holland Growth Agenda was launched in 2021 (Event 43). It is a joint strategic initiative by the Province of South Holland, the Economic Board Zuid-Holland (EBZ), municipalities, knowledge institutions, and private businesses. Its core purpose is to reverse the region's lagging economic growth, counter rising unemployment following the COVID-19 pandemic, and collectively solve massive regional infrastructure and climate challenges. The agenda targets public-private investments in both developing and commercializing digital technologies such as AI and cybersecurity, and facilitating the energy transition. The funding mechanism in the Growth Agenda also acts as a pipeline to pull further financial support from the National Growth Fund. Furthermore, in 2022, the South Holland Digitalization Agenda (Event 44) was developed by the Digital Economy Taskforce (Event 40) that was formed in 2019 within the Economic Board Zuid-Holland, particularly focuses on integrating smart grids, data sharing, and AI to optimize energy usage and combat grid congestion.

At the regional level, in 2016, the Roadmap Next Economy (Event 49), a long-term regional strategy for the Rotterdam-The Hague metropolitan area that highlighted the digitalization and energy transitions as intertwined pathways, in particular, the role of smart grid that leverages ICT solutions to increase the control and flexibility of energy system for the transition towards net zero. In other follow-up regional strategies, the idea of leveraging digitalisation to facilitate energy transition was further strengthened and implemented, such as the Calibrated Rotterdam Port Vision 2030 in 2019, the Rotterdam Port Vision 2050 in 2021, the Rotterdam-Den Haag Regional Energy Strategy and Rotterdam-Moerdijk Cluster Energy Strategy (Events 52, 56, 54, 55).

Since 2022, digitalization and greening were integrated into a coherent approach for energy transition both at the national, provincial and regional levels.

At the national level, the National Energy System Plan (Event 22) in 2023 framed the future Dutch energy system around electricity, hydrogen, carbon carriers and heat and highlighted data and digitalisation as a public interest. The new Energy Act law in 2024 (Event 23) introduces new rules for energy-data exchange. This matters for industrial electrification and flexibility because firms need better access to energy data to optimise demand, trade flexibility, participate in local energy systems and manage congestion. The national Action Agenda Digitalisation of the Energy System (Event 24) in 2025 connects digitalisation to the energy system and gives direction to how data and digitalisation should support a reliable, affordable and sustainable system in executing the vision outlined in the National Energy System Plan. Within the Digitalisation program of the Top Sector Energy, different themes, such as cybersecurity, data governance, reference architecture, were added for addressing challenges in the energy sector. Particularly, after the adoption of the National Cybersecurity Strategy (Event 33) in 2022, the National Growth Fund started the CS4NL, a broad cybersecurity programme for the top sectors, in 2023.

At the provincial level, the Innovation Coalition for Cybersecure Energy Transition (Event 48) was formed in 2025 with the goal to position South Holland as a frontrunner in a 'secure-by-design' energy system – and to successfully market this knowledge and expertise in the Netherlands and Europe. Port of Rotterdam and many other actors based in the Rotterdam-Rijnmond region were partners that founded the coalition.

At the regional level, the 2024 Cluster Energy Strategy Rotterdam-Moerdijk (Event 58) highlighted the role of digital tools in confidential data sharing, demand forecasting, infrastructure modelling and system optimisation for energy transition. Furthermore, the strategy also identifies the role of digital solutions such as energy-system modelling, local energy trading, flexibility management and digital twins in solving the issue of grid congestion.

Analysis of the Twin Transition Dynamics

The analysis shows that the transition of the energy sector in the Rotterdam-Rijnmond region was a process of national steering, provincial coordinating and regional implementation based on local conditions.

During the early phase at the national level, climate, energy and innovation policies shaped the direction of the greening-related changes and how these changes are governed in a coalition building process. For example, the Top Sector policies created the overarching triple-helix model through public-private partnerships. Based on this governance approach greening is driven both by regulatory compliance and efficiency logics. The Paris Agreement in 2015 appears to accelerate the green transition with an increasing integration of both greening and digitalisation occurring. After 2022 mainly integrated twin transition developments take place. The coupling of both transitions is deliberately driven at the national level and progressively integrated across state and regional scales.

The provincial and regional government was mostly implementing the national policy agendas through coordination, spatial prioritisation, and ecosystem-building. Particularly for the regional level, due to the unique case of city-port-region transition, many changes take place in a hybrid governance arrangement linking municipal governments, the port authority, national ministries, provincial coordination, firms, knowledge institutes, and intermediaries.

As the low-carbon transition of the energy system proceeded, the role of the digitalisation in the energy system has become increasingly prominent. This led to the integration of greening and digitalization at both national, provincial and regional level. Further, after 2022 more emphasis is placed on cybersecurity in the scope of the energy transition.

RQ2: How are upskilling and reskilling initiatives developing in the context of the Twin Transition?

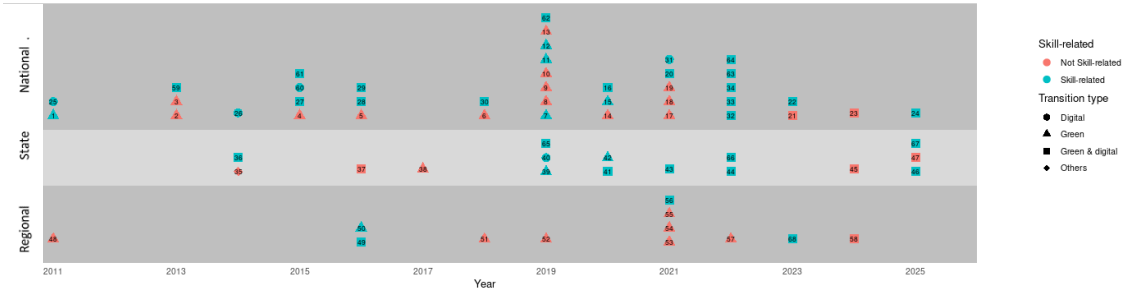

Figure 20: Transition Topology depicting institutional changes related to skill (and non-skill)-related initiatives as well as transition type across multiple spatial scales in the energy sector in Groot-Rijnmond, the Netherlands (2011-2025).

Figure 20 shows that in the transition of the energy sector upskilling and reskilling initiatives develop in parallel with the transition (pattern d).

Description of the Patterns, Sequences and the underlying Micro-Dynamics in the Empirical Case

The skilling-initiatives in the Rotterdam-Rijnmond region was mostly through the Human Capital Agenda at different spatial levels. At the national level, the Human Capital Agenda (HCA) was already explicitly planned in the National Top Sectors Policy in 2011 (Event 1), indicating that large and small firms, scientists and government needed to cooperate within top sectors, and that top sectors strengthen the economy through innovation, internationalisation, societal problem-solving, scientific research and human capital.

In 2013, the Dutch government commissioned the Platform Talent voor Technologie (PTvT) (formerly known as Platform Beta en Techniek), an independent organisation (foundation) created by the Ministries of Economic Affairs (EZK), education (OCW) and Social Affairs (SZW) in 2004, to coordinate the implementation of the Technology Pact in the Netherlands (National Techniekpact). The Technology Pact (Event 59) is a joint initiative of central government, the organized business community, the trade unions, the education community and the regions that uses a structural approach to ensure a well-educated workforce and increase the number of technicians and to strengthen beta, technical and technological skills on the Dutch labour mark and reduce the shortage of technical profiles. Besides it's coordinating role, PTvT also develops and implements a wide variety of implementation programs throughout the education chain. This includes the development, piloting and ongoing support of the Centres of Expertise in higher education, Centres of Vocational Excellence in VET and the SME action agenda aimed at digitalization, sustainability and inclusion related activities for SMEs through public-private partnerships. This was through its subsidiary Katapult, a national network which supports various public-private partnerships in the higher education and vocational training sectors.

The objectives of Technology Pact were further incorporated in the Human Capital Roadmap Topsectoren 2016-2020 (Event 61). The major changes compared to the Human Capital Agenda in the initial Top Sector were the cross-sectoral coordination, the introduction of learning communities that integrate learning, working, innovating and researching in public-private partnerships and the introduction of lifelong development. Following the implementation of

Multi-annual Mission-oriented Innovation Programs among Top Sectors in 2019 (Event 11), Dutch Top Sectors jointly developed the Human Capital Roadmap Topsectoren 2020-2023 (Event 62), framing the labour market challenges around major transitions in energy, health, food, water and safety, arguing that the Netherlands needs enough people with the right skills to develop and apply breakthrough solutions. Particularly, the Human Capital Agenda of Top Sector Energy states that the energy transition is a "job engine" requiring different skills and that labour-market and education systems are crucial for achieving climate goals. It also identifies labour shortages as a major threat to the energy transition and describes the HCA as agenda-setting, driving and facilitating: putting shortages on the political agenda, encouraging follow-up, bringing parties together and making funding accessible.

Besides the top sectors, since 2021, the National Growth Fund (Event 16) incorporated dedicated Human Capital Agendas into its major innovation programs, such as GroenvermogenNL dedicated to the green hydrogen transition. These embedded programs are designed to upskill workers, align educational curriculum with emerging industries, and foster learning communities connecting industry, education, and research. Furthermore, the National Growth Fund also invests significantly in education and lifelong learning. For example, LLO-Katalysator is a multi-year program funded by the National Growth Fund through which educational institutions from secondary vocational education, universities of applied sciences, and universities provide a strong boost to lifelong learning (LLL), both nationally and regionally. The goal of the LLO-Katalysator is to ensure that organizations and professionals remain continuously aligned with a rapidly changing society and labour market. In 2023, the LLO-Katalysator officially launches with a pilot in the energy and raw materials transition.

In response to the labour shortages in jobs essential to for the climate and digital transitions, the Action Plan for Green and Digital Jobs (Event 63), developed since 2022, was adopted by the Dutch Government in 2023. The Action Plan was a joint effort of sectors, regional governments, education, national government and other parties, initiated by the national government through four ministries. It includes measures to address labour market challenges in sectors with jobs that are important for the climate and the digital transition. The Action Plan contains the following priorities: strong technical education and technology promotion; cooperation between education and business; offering education more in line with the needs of employers; exploration of how projects within shortage sectors, including technology, can benefit even more be stimulated and strengthened within mandatory social service.

In 2022, a coherent approach for the Human Capital Agenda Energy Transition (Event 64) was introduced to effectively manage all investment programs aimed at addressing labour market shortages in the energy transition including EU's Just Transition Fund, and several programmes in the National Growth Fund, such as GroenvermogenNL and LLO-Katalysator. Also, human capital agenda was implemented in the Digitalisation Program within the Top Sector Energy with particular focus on the digital skills. The coherent approach aims to increase the feasibility of the National Energy System Plan and ensure a sufficient supply of qualified people for the energy transition. The National Energy System Plan in 2023 (Event 22) explicitly recognised labour-market constraints. It refers to the Action Plan for Green and Digital Jobs and notes that the energy transition will require more labour, more implementation capacity, standardisation, better cooperation, and labour-saving innovation.

The human capital agenda was also implemented at the provincial level and the regional level. At the provincial level, the Human Capital Agreement South Holland (Event 65) was the major turning point. On 24 June 2019, 65 parties from business, education and government signed the agreement because South Holland faced the largest labour shortages in the Netherlands. The

agreement aimed to make the province of South Holland nationally and internationally competitive by better using the talent of workers. The agreement covered lifelong learning, labour-market resilience, activation of unused labour potential and attraction/retention of international talent. Several projects were launched in following years that concerns the upskilling and reskilling for digital and green transitions of the energy sector, including SMITZH-3 – Mensen aan de Slag, We IT Zuid-Holland, Cybersecurity, and EnergySwitch.

The Human Capital Agreement was later adopted in the Growth Agenda South Holland (Event 43) in 2021 which explicitly linked economic restructuring to upskilling 55,000 workers and flex workers and guiding 10,000 people into future-proof work. In 2022, the South Holland Human Capital Agenda 2.0 deepened the 2019 agreement. It identified four labour-market problems: South Holland's severe labour shortages, fragmented labour-market mobility, poor activation of unused labour potential, and insufficient organising capacity at provincial level. It expanded the original four routes into seven, adding more explicit attention to technical occupations, inclusiveness and changes in national regulation. The most recent update was the Human Capital Agenda South Holland 2025–2030 signed by more than 200 organisations in 2025 (Event 67). It sets measurable goals including 55,000 workers given development opportunities, 10,000 work-to-work transitions, 40,000 non-working jobseekers into work, and 1,000 international knowledge workers attracted and retained. It also states that employers and funds for education and development invest in worker development and work-to-work guidance, while municipalities, employee insurance agency (UWV) and work centres help people currently outside work participate without unnecessary bureaucratic barriers.

Motivated by the persistent labour shortages, major vacancy pressure, the need for transition-specific craftsmanship, and the need to avoid the energy transition slowing down because the workforce pipeline lagged behind, the major regional initiative the Human Capital Coalition Energy Transition (HCCE) began in January 2023 (Event 68). The Human HCCE is the regional platform for talent policy in the Port of Rotterdam. The partners include Deltalinqs, Port of Rotterdam, Municipality of Rotterdam, Hogeschool Rotterdam, Techniek College Rotterdam, Albeda, Zadkine, STC, EIC, JINC, Maritime Museum Rotterdam, and TNO. They collaborate on the employment and education offerings for the Port and Industrial Complex of Rotterdam, in order to attract and retain skilled workers and talent, and used Just Transition Fund and National Growth Fund support related labour-market projects.

Analysis of the Dynamics of Skilling Initiatives

The skilling initiatives are driving by the concerns of labour shortages and the recognition of human capital as the engine for economic development and transitions at both national, provincial and regional level. Similar to the twin transition dynamics, the dynamics of skilling initiatives was a process of national steering, provincial coordinating and regional implementation based on local conditions. Similarly, to the pattern observed in RQ1, skilling was proactively integrated in the transition early on.

The human capital agenda was one key component of the national Top Sector Policy from its inception. It is also governed and implemented in similar coalition-based process that involves public-private partnership. Over the years, the implementation of the national human capital agenda became increasingly institutionalized and coordinated between sectors and within the education chain including life-long learning across different regions in the Netherlands with regional actors involved in the national network. However, persistent skill mismatches remain, as evidenced by the policy responses developed after 2022 explicitly targeting these gaps. At the provincial and regional level, human capital agenda was coordinated and implemented in the

similar coalition-based process. Particularly, many actors in the Rotterdam-Rijnmond region including the Municipality of Rotterdam, Erasmus University of Rotterdam and other education providers, Port Authority of Rotterdam and other private employers are the initiating partners of the first Human Capital Agreement South Holland in 2019.

iii. Łódzkie (UW)

RQ1: To what extent is a Twin Transition emerging at the regional level within the institutional context of the labour market?

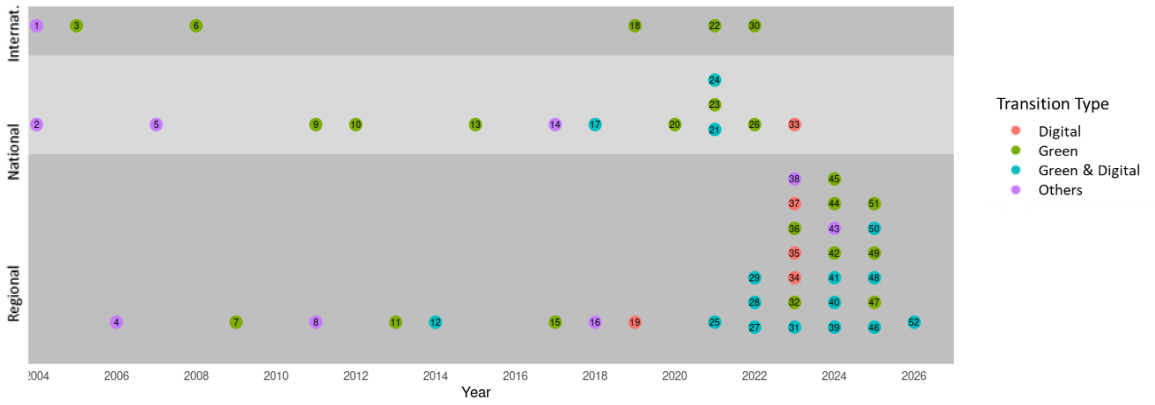

Figure 21: Transition Topology depicting institutional changes related to greening and digitalisation across multiple spatial scales in the energy sector in Łódzkie, Poland (2004-2025).

Figure 21 illustrates that, between 2004 and 2020, the primary emphasis was on green transition-related initiatives at the national and regional level, while digitalisation played a less prominent role (pattern a). Most greening related changes took place at the national level, only a few greening related changes occurred at the regional scale. From 2020 onwards, green and digital related changes accelerate in parallel (pattern c), while changes which integrate both greening and digitalisation increasingly occur (pattern d).

Description of the Patterns, Sequences and the underlying Micro-Dynamics in the Empirical Case

Between 2004 and 2020, the primary emphasis was on maintaining Poland's existing energy system based on coal and conventional sources, including in the Bełchatów region. Desk research showed that Poland's accession to the European Union (Event 1) was the first development to influence the country's energy transition, including the transition of the Bełchatów region. As an EU Member State, Poland was obligated to implement European policies such as the EU Emissions Trading System (ETS) Directive (Event 3) and the emission reduction targets established in the Climate and Energy Package (Event 6).

However, in the initial years following EU accession, Poland attempted to slow the advancement of the European Union's climate policy, particularly the implementation of EU directives at the national level. In 2006, a decision was made to construct a new 858 MW unit at the Bełchatów Power Plant (Event 4), which became operational in 2011 (Event 8). The investment was approved at the national level despite clear signals from the European Union regarding the need to reduce greenhouse gas emissions and decrease energy production from fossil fuels. The mindset focused on prolonging coal extraction for as long as possible was also evident in the launch of the Carbon Capture and Storage (CCS) project in Bełchatów (Event 7).

In 2004, the government consolidated three major power plants into a single holding company, BOT (Bełchatów–Opole–Turów Holding), headquartered in the region (Event 2). This move

centralized management and strategic planning capacities in Łódź/Bełchatów. Later, BOT was merged into the centrally managed Polish Energy Group (PGE), based in Warsaw (Event 5). As a result, decisions about the phase-out of the mine and power plant in Bełchatów have since been made at PGE headquarters, rather than locally by PGE GiEK, the entity managing the Bełchatów coal mine and power plant.

Between 2017 and 2018, two important developments took place that were aimed at sustaining coal extraction and conventional energy production in Poland. The adoption of the Capacity Market Act (Event 14) was intended to provide financial support for conventional power generation, while the adoption of the Spatial Development Plan enabling the development of the Złoczew lignite mine (Event 16) was designed to facilitate the continuation of coal extraction in the region.

Nevertheless, there were some early developments during this time period indicating a mindset shift. The abandonment of the CCS demonstration project in 2013 (Event 11) represented an important change, indicating that incremental greening of coal-based technologies was not a viable transition pathway and directing attention towards alternative energy sources including renewable energy (Event 13), nuclear power (Event 10), and energy efficiency measures (Event 9).

In 2014, the Regional Innovation Strategy (RIS3 LORIS 2030) was adopted, identifying the “Modern Power Industry” as one of the region’s Smart Specialisations (Event 12). The strategy aimed to facilitate access to European funding for the energy sector in Poland. Within this framework, the energy sector was formally recognised as a key specialisation of the Bełchatów region. Moreover, it was the first initiative to address both digital and green transformation simultaneously.

During the same time period, a bottom-up regional initiative emerged with the adoption of the Anti-Smog Resolution for the Łódzkie Voivodeship (Event 15). The anti-smog resolution reflected growing public and regional awareness of environmental and air quality challenges. Furthermore, the resolution spurred grassroots transformation at the household level by encouraging the replacement of traditional heating systems and investment in energy efficiency. This created a growing market for renewable energy sources and skilled employers (e.g., heat pump installers and related services), generating new employment and skills demands independent of the future of large-scale coal power plant and mining operations.

After 2020, the topic of green transition and phase-out of the mine accelerated in the region, as the local stakeholders emphasized during the interviews.

The first national-level document to mention, in very general terms, the region's green transition was the Energy Policy of Poland until 2040 (Event 21), published in 2021. However, it provided only very general information, without a detailed action plan. The same year PGE announced the schedule for closing mining fields (2028-2038) and power units (2030-2036) (Event 23). This transformed "transition" from a theoretical concept into a concrete timeline, but without any strategy provided by PGE or regional and national authorities.

The rapid concentration of transition-related events, was driven primarily by the EU Just Transition Fund rather than by national policy or endogenous regional initiative. In 2021, the Polish government also announced plans to develop the National Just Transition Plan (Event 24), a strategic document intended to define intervention areas and identify regions eligible for support from the Just Transition Fund (€3.85 billion). The main objective of the National Just Transition Plan was to mitigate the negative impacts of the energy transition and decarbonisation on mining regions by supporting economic diversification, job protection, and social cohesion. Despite its significance, the document was never finalised.

Interview partners agreed that the establishment of the Just Transition Fund (JTF)—a central pillar of the European Green Deal and the European Commission's flagship initiative served as a catalyst for the energy transition in the Bełchatów region (Event 29; Interview01,02,05,07,08,10).

The significance of the JTF becomes clearer when viewed in the broader context of the European Green Deal and its influence on Poland's national policy. The European Commission's establishment of the European Green Deal in 2019 was the first development to significantly influence Poland's national policy (Event 18). At first, Polish authorities resisted its adoption, as it demanded a far-reaching transformation of critical economic sectors, including energy, heavy industry, and agriculture. The government initially aimed to maintain the status quo. However, with the launch of new financial instruments such as the Just Transition Fund (JTF) in 2021, the national authorities began negotiations to ensure that Poland would benefit from additional funding to support the transformation process.

In 2021, the Commission proposed including the Bełchatów region in the Just Transition Fund financing scheme. In order for the Łódzkie Voivodeship to apply for financial support from the Just Transition Fund, it was required to prepare two key documents: the Territorial Just Transition Plan (TJTP) (Event 27) and the Development Strategy for the Łódzkie Voivodeship 2030 (Event 28), an institutional document setting out the long-term vision for the region's socio-economic transformation. Both documents were adopted in 2022. In December 2022, the European Commission formally approved the Territorial Just Transition Plan for Łódzkie, thereby unlocking €369 million from the Just Transition Fund to support the region's transition process (Event 29).

The main factors that accelerated the green transition in the Bełchatów region were economic and financial considerations. Coal extraction in Poland is becoming increasingly unprofitable. Therefore, when the opportunity arose to obtain additional funding for transformation processes through EU resources (the Just Transition Fund – Event 29), the national and regional authorities saw it as an opportunity to initiate the transformation, recognising that the green transition was inevitable.

As can be seen, the green transition is primarily implemented through a top-down governance approach, with initiatives flowing directly from the European level to actors in the Bełchatów region (Just Transition Fund). The implementation of the Just Transition Fund (JTF) in the Łódzkie Voivodeship (Event 29) contributed to accelerating the energy transition process through the funding of numerous initiatives related to the green and digital transformation (Events 31, 38, 39, 40, 46, and 52). The earlier drafted Regional Innovation Strategy (RIS3 LORIS 2030) designation served as an important ex-ante condition for future access to EU funding, enabling the development of advanced innovation ecosystems, such as the Digital Innovation Hub established in 2023 (Event 34).

Conversely, growing awareness among local stakeholders in recent years has spurred a range of bottom-up initiatives related to the green and digital transformation (Events 19, 30, 35, 41, 44, 45, 47, 48, 50, and 51). Many stakeholders have recognised that failing to act now could result in missed investment opportunities and lost benefits associated with the transition process, ultimately undermining the future development of the Bełchatów region. Although these efforts remain fragmented and insufficient relative to the region's significant challenges, the shift in mindset has been instrumental in mobilising local actors and encouraging sustained engagement in the transition process.

Meanwhile topics related to the digital transformation appear separately and are not strongly interconnected with the just transition process in the region. The process of digital transformation at the Bełchatów power plant and mine progressed in line with market trends in the energy sector. Part of the work has been automated over the past 10 years (2016-2026), but these changes were driven by the optimisation of extraction processes (Event 33 and 37). Only the digital

improvements considered necessary were implemented, given that the complex is scheduled to be phased-out in the 2030s. Digital transformation is taking place largely outside the phasing-out process for the mine and power plant (PGE is not investing in the digital transformation in the complex, which will be closed).

In addition, there are several initiatives aimed at accelerating the digital transformation that are financed through the Just Transition Fund. These mainly concern upskilling and reskilling and will therefore be described in detail in RQ2.

Analysis of the Twin Transition Dynamics

The analysis of the energy sector in Łódzkie shows a prolonged period of active resistance to a green transition, with the transition accelerating only after 2020. The overwhelming majority of transition-driving events originate at the EU level which are subsequently translated to the national and regional level, rather than proactive responses emerging at the regional level. Poland's accession to the European Union initiates the first transition pressures, however long-term investment in coal-based electricity generation led to a prolongment of the existing regional trajectory. Only the Just Transition Fund financing together with the declining economic viability of coal initiate the uptake of the green transition in Łódzkie. This indicates that the green transition dynamics in this case were top-down and externally driven, motivated by compliance and efficiency logics.

Digitalisation efforts were driven by cost reduction and operational efficiency. The coupling of greening and digitalisation remains weak and largely absent, with the two processes developing in parallel rather than in an integrated manner. Only partial and niche-specific signs of integration emerging through JTF-funded upskilling initiatives emerge after 2020.

A number of key decisions influencing the region's future economic and energy profile remain under consideration at the national level, limiting the regional actors' influence over these processes. While after 2020 bottom-up initiatives related to the green and digital transformation increasingly emerge, they remain uncoordinated. This might be due to the absence of intermediary actors at the regional scale.

RQ2: How are upskilling and reskilling initiatives developing in the context of the Twin Transition?

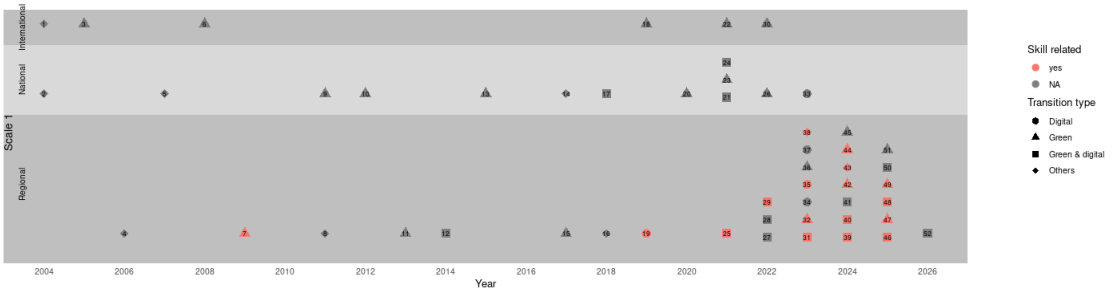

Figure 22: Transition Topology depicting institutional changes related to skill (and non-skill)-related initiatives as well as transition type across multiple spatial scales in the energy sector in Łódzkie, Poland (2004-2025).

Figure 22 shows that initiatives related to upskilling or reskilling are relatively rare before 2021. Before 2021 only two skill-related events (one related to greening and the other one related to digitalisation) take place at the regional level, while at the national and international scale no

skilling initiatives are depicted. After 2020, skilling initiatives develop in parallel with the transition. The main reskilling and upskilling initiatives combine the development of green skills with digital competencies.

Description of the Patterns, Sequences and the underlying Micro-Dynamics in the Empirical Case

Between 2000 and 2019, there were few reskilling or upskilling initiatives in the Bełchatów region focused on the digitalization or greening. In line with the resistance towards the phase-out of fossil energy and the initial investment into CCS in the early phase, skilling was planned for CCS technology. As a result of the abandonment of the CCS demonstration project (Event 7), in practice no reskilling or upskilling activities related to CCS could be implemented. With regard to digital skills, the first major development came later in 2019 with the establishment of the 5G Competence Centre at Łódź University of Technology (Event 19). By investing early in expertise related to 5G and the Internet of Things (IoT), the university began cultivating digital capabilities before the energy sector had clearly defined its need for such skills. This proactive strategy paved the way for the later swift launch of a Cybersecurity degree programme in 2023, coinciding with a more pronounced demand for these competencies (Event 35). These initiatives were primarily a response to the growing market demand for advanced digital competencies. Interview partners consistently emphasised that such competencies have become increasingly important across the Polish economy in recent years (Interviews 05, 10, 13, and 15).

As described under RQ1, in 2020, PGE announced plans to decommission the Bełchatów Power Plant and gradually phase out the Bełchatów lignite mine (Event 21), marking a pivotal moment for upskilling and reskilling initiatives targeting the energy sector workforce. The following year, PGE GiEK and the Marshal's Office of the Łódzkie Voivodeship collaborated to establish the Competence Development Centre (CDC, Event 25), representing a significant advancement for workforce development in the region. The CDC, a dedicated facility, coordinated reskilling efforts in the Bełchatów region and worked closely with local vocational schools. The establishment of the Competence Development Centre (CDC), initiated by the Marshal's Office of the Łódzkie Voivodeship, aimed to encourage the active involvement of PGE GiEK—the region's main energy company and the owner of the Bełchatów mine and power plant—in the transition process.

The establishment of the CDC was followed by several additional reskilling and upskilling initiatives supported by the Just Transition Fund (JTF). In 2023, the first 'Competences for the Green Economy' Call for Proposals was launched under the Just Transition Fund (JTF), underlining the operational rollout of JTF funding in the Łódzkie Voivodeship. Following the approval of the Territorial Just Transition Plan (Event 29), the Regional Authority initiated competitive calls for proposals supporting reskilling projects. This, in turn, encouraged training providers to submit grant applications and established a framework for delivering training programmes in the coming years.

In 2023, the Regional Labour Office launched the Academy of Transition project (Event 38) —the first major operational initiative funded by JTF with a focus on human capital development. The project offers career counselling and skills assessments for mining sector employees, aiming to evaluate their potential for employment in the information technology (IT) and renewable energy (RES) sectors. In this way, it has established a diagnostic foundation for future large-scale reskilling efforts.

Another JTF-funded initiative supporting reskilling and upskilling was the pilot programme Professional Reactivation, launched in 2024 (Event 43). The project was coordinated by the Competence Development Centre of the Łódzkie Voivodeship and PGE Polska Grupa

Energetyczna in Wola Grzymalina, with the Bełchatów–Kleszczów Industrial and Technology Park Ltd. serving as the principal implementation partner.

Each participant receives a training voucher to upgrade their skills and qualifications. Eligible training options include courses on green skills, digital competencies, and broader professional development, all listed in the Development Services Database (Baza Usług Rozwojowych – BUR) and chosen based on an individual skills assessment. Participants are free to choose their preferred training courses and receive support through consultations with a career advisor. Here, the European Commission's approval of JTF funding for the Łódzkie Voivodeship in 2022 (Event 29) was essential for launching and successfully implementing the programme.

Other JTF-supported initiatives included the Transformation Zone (Event 39) and Development Zone 3.0 (Event 40), both coordinated by the Łódź Special Economic Zone and launched in 2024. The Transformation Zone programme (Event 39) is designed to strengthen competencies and improve labour market prospects by supporting the reskilling of individuals who study, work, or reside within the area covered by the Territorial Just Transition Plan for the Łódzkie Voivodeship. This programme adopts the same voucher-based model as Professional Reactivation, providing each participant with a training voucher that can be used for any eligible course aimed at developing their skills and qualifications.

The Development Zone 3.0 programme (Event 40) targets small and medium-sized enterprises (SMEs) in the Łódzkie Voivodeship. Through a voucher-based funding scheme administered by the Łódź Special Economic Zone, employers can enrol their employees in training programmes. This funding is primarily intended to foster the development of competencies related to the green transition, the circular economy, and digital skills.

In addition, the Bełchatów Energy 4.0 Reskilling Pilot Programme, titled Pathway to Employment After Coal (Event 46), was launched in 2025. The programme was also funded through the JTF (Event 29) and aimed to provide training in the installation of renewable energy systems (RES) and in digital grid monitoring. It represents coordinated initiative integrating green and digital skills development, reflecting the operational implementation of the twin transition in the regional labour market.

Although several reskilling and upskilling initiatives have been launched since the introduction of JTF funding, stakeholders emphasise that these efforts remain fragmented, insufficiently coordinated, and inadequate to address the needs of the just transition area, which covers 35 municipalities. They also point to the lack of a comprehensive labour market analysis and a unified long-term workforce development strategy (Interviews 02, 16).

Analysis of the Dynamics of Skilling Initiatives

In the early phase, skilling initiatives were largely absent. From 2021 onward, up- and reskilling activities increased, mirroring the broader transition trajectory identified in RQ1. As in RQ1, most skill-related events are tied to EU-level developments and the phase-out decision. Notably, the European Commission’s approval of JTF funding for the Łódzkie Voivodeship in 2022 (Event 29) was the basis for the launch and financing of most skilling initiatives. This pattern indicates that skilling emerged reactively rather than proactively responding to mounting transition pressures that had been building before 2021.

Before 2021, higher education institutions and economic actors primarily drove skilling. After 2021, a more diverse mix of actors became involved. The creation of a new organization by the

Marshal's Office and PGE highlights the emergence of new forms of cooperation during the transition. Overall, economic and public actors appear to be the main drivers of skilling after 2021, while universities have been less active. Target groups are mainly employees and students, with programs delivered primarily through individually targeted offers rather than firm-internal training.

Although EU funding rules mandate coupling green and digital skills, the emphasis on individual choice in selecting specific training means this coupling remains abstract. Information technology and renewable energy are cited as fields for reskilling, but no clear priority emerged. Consequently, the uncoordinated nature of the transition described in RQ1 is also evident in the skilling response, which lacks place specificity.

e. Agriculture Sector

The Agriculture Sector is the focus of two case studies by the partners BOKU and LSE. The updated data basis for the results of each case are summarized below (Table 5):

Table 5: Data basis for Task 4.2 in the Agriculture Sector

BOKU	LSE
12 stakeholder interviews - Academia (4) - Private company (2) - Regional development agency - NGOs (2) - Chamber of Agriculture - VET provider (2)	20 stakeholder interviews - Academia (3) - Private company (8) - Private sector organisation (2) - Local action group (2) - NGO (2) - (Ex-)Policy-maker - Local government (2)
Document analysis	Document analysis

i. Styria (BOKU)

RQ1: To what extent is a Twin Transition emerging at the regional level within the institutional context of the labour market?

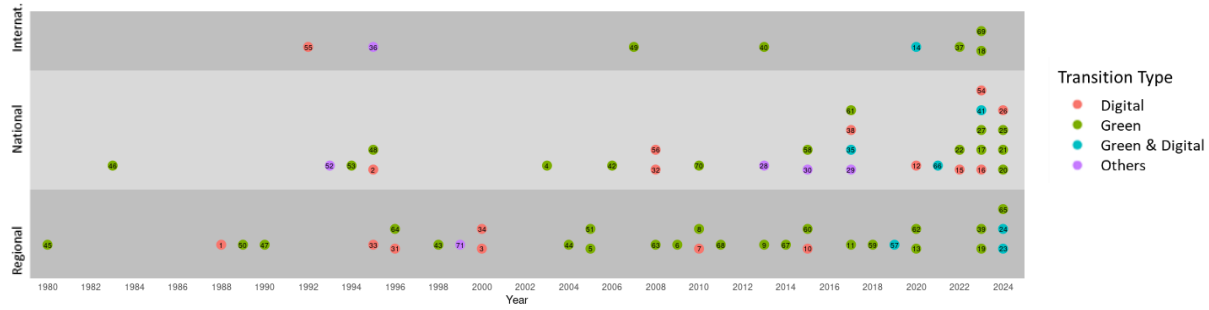

Figure 23: Transition topology depicting institutional and organizational changes related to greening and digitalisation across multiple spatial scales in the agricultural sector in Styria, Austria (1988-2024).

In the topology (Figure 23) of the Styrian agriculture case, initially, changes relevant in particular to greening take place before 1994 at the regional scale (pattern a). Starting in 1995, green and

digital events take place in parallel at the regional and national level (pattern c). After 2016, especially at the regional level more greening related events than digital events occur with some events occurring which combine both transitions (pattern a and pattern d). At the national scale, digital changes predominate between 2017 and 2022 (pattern b), from which onwards an increase in green-related events occurs (pattern a).

Description of the Patterns, Sequences and the underlying Micro-Dynamics in the Empirical Case

First, changes that are specifically related to greening occur at the regional level already in the 1980s. The desk research revealed that early sustainability related initiatives were mainly related to organic farming initiatives rooted in Styria, such as the founding of the Organic Harvest Styria in 1980 (Event 45). These so-called organic pioneers were a group of about 30 farmers which established their own organic production standards. Organic standards were increasingly institutionalized at the national scale as well as at the Styrian level with the first Austrian organic certification standards introduced in 1983 (Event 46) and the first Styrian funding mechanism for organic agriculture established in 1990 (Event 47), indicating a bottom up dynamic.
In parallel, the earliest digitalisation-related changes emerge in the late 1980s, driven by the chamber of agriculture as a semi-public actor. The establishment of the Agricultural IT Club Styria in 1988 (Event 1) is the first documented institutional digitalisation initiative, reflecting farm management efficiency needs rather than any regulatory requirement (Interview03).

Austria's accession to the European Union in 1995 (Event 36) represents the most significant external impulse of this period, simultaneously accelerating both transitions, but through different mechanisms and to some extent affecting different actor groups. With regards to digitalisation, EU membership introduced detailed documentation requirements that triggered a wave of digital farm management initiatives (Interview03). The introduction of the digital cattle database in 1995 (Event 2), the workgroup consultancy on pork production in 1998 (Event 31) which was subsequently expanded to cover milk and arable farming represent some of those changes (Events 34, 71).

For greening, EU accession strengthened the existing bottom-up greening trajectory through institutional changes such as the national ÖPUL environment program (Event 48), which offered financial compensation for organic practices. This program further institutionalized organic agriculture dynamics (Interview01). However, due to the incentives for organic conversion, organic pioneers feared a dilution of the organic movement's early values. Furthermore, European funding supported regional value chain initiatives and enabled a greening process focused on shortening value chains closely related to the organic agriculture greening dynamics. Several events, aimed at strengthening regional agricultural value chains, such as the establishment of regional quality labels and protected origin schemes (e.g., Styrian horseradish PDO, Event 6), enabled by European regulation (Interview10). Similarly, the establishment of the first culinary regions in Styria (Event 5) and the launch of the brand "Styrian Vegetables" launched by the association of the Styrian vegetable farmers in 2008 (Event 63) represent changes that build upon shortening regional value chains (Interview10).

From the early 2000s onwards and through the 2010s, technological innovation in agriculture accelerated with the introduction of GPS-guided tractors and precision farming technologies, marking a shift towards digital field management and data-driven decision-making. In this regard the chamber of agriculture took on the role of a technology transfer agent between technology providers and large-scale farms (Interview01). However, the institutional and organisational response lagged significantly behind: funding programmes for precision farming remained scarce and became available only slowly. One change represents the introduction of an investment

subsidy for steering systems under the rural development programme 2014-2020 in 2017 (Event 35). A further event was the provision of the APOS RTK correction farmers in 2021 (Event 66), which substantially lowered the barrier to entry for precision farming technologies (Interview03, 11). These events occurred primarily at the national level.

During the 2010s, distinct greening streams developed in parallel at the regional level. On the one hand, the Maschinenring began facilitating photovoltaic energy groups (Event 8; Interview03), reflecting an efficiency-driven energy transition logic within the agricultural services sector. On the other hand, a range of intitiatives and projects e.g. the introduction of the brand for Styrian vegetables “Mei Guat” and the so-called Organic Model Regions (Events 9, 11; Interview07) continued both the values-based, short supply chain trajectory and the organic agriculture movement.

After 2015, the implementation of the CAP 2014–2020 programming period (Event 40) introduced mandatory greening payments as a third pillar of direct payments and the associated ÖPUL 2015 (Event 70) marked a significant acceleration of greening-related institutional changes at the regional level (Interview01). These compliance and incentive-driven changes affected both organic and conventional farmers. The Styrian chamber of agriculture and Bio Austria Styria took on expanded roles as advisory and implementation intermediaries, translating the new programme requirements into concrete farm-level support. A significant organizational change was the establishment of the organic committee of the Styrian chamber of Agriculture (Event 67) indicating an increasing integration of both greening streams.
The post-2020 period marked the intensification of the green transition and the first observable shift towards integrated twin transition changes, driven by two distinct developments. At the EU level, the renewed CAP (Event 69) introduced enhanced conditionality and eco-schemes that explicitly link environmental compliance with digital documentation and reporting requirements. One change directly connected to the reformed CAP are digital documentation systems for plant protection (Event 14; Interview03), simultaneously supporting environmental monitoring and digital governance and therefore a direct expression of this regulatory twin transition coupling logic. The introduction of EU sustainability reporting requirements (Event 18) further drove the need of especially large-scale farms to understand their environmental impacts (Interview01).

At the regional level, the Covid-19 pandemic independently accelerated the uptake of digital platforms for regional food distribution such as the Markt.at (Event 23) and the Direct Marketing Hub Vulkanland in 2024 (Event 24; Interview07). These platforms combined digitalisation with the long-established greening logic of shortening regional value chains, producing integrated Twin Transition changes deliberately rather than driven by regulatory pressure. Nevertheless, interview partners reported challenges stemming from uneven technological readiness and interoperability issues among small-scale distributors (Interview07).

Similarly, several changes from 2020 onwards are related to market gardening (Events 12, 21, 22) which is based on a bio-intensive small-scale vegetable production systems and direct marketing. The operational group Market Gardening founded in 2022 (Event 22) as the first large-scale European EIP-AGRI innovation project on this concept, brought together Organic Harvest Styria and the chamber of agriculture to investigate bio-generative practices with digital planning tools, therefore representing a case in which organic agriculture is started to be coupled with digitalisation (Interview02).

Analysis of the Twin Transition Dynamics

Overall, in the agriculture sector in Styria the majority of institutional changes relate to the green transition, particularly through greening policies, regional value chain initiatives, and organic farming networks. Digital transition events are concentrated around farm management technologies, digital data systems, and digital learning formats.
The topology shows a pattern in which these greening and digitalisation related events develop in largely separate trajectories, driven by different actors and logics, in a sequential manner. Overall, this resulted in weak coupling between greening and digitalization. More recently an integration of both transitions is becoming visible, yet, in completely different areas.

Greening emerged early on through bottom-up networks, driven by small farmers which founded networks and focused on organic farming and regional value creation. The accession to the European Union further influenced the greening trajectory by strengthening policy frameworks, sustainability standards and funding mechanisms. However, the different greening trajectories remain largely separate.

Institutional and organizational changes with regards to digitalisation (e.g., IT networks and digital farm databases) coincide with the accession of Austria to the European Union in 1995. These changes were supported mainly by the chamber of agriculture.

Hence, one driver of both transitions at the regional level is the EU policy and funding architecture. Yet, there are differences regarding to the actors that are affected and that implement respective institutional and organizational changes at the regional level. With regards to digitalization, the chamber of agriculture drove the digital transition by acting as technology transfer agents between technology providers and more large-scale farms, that are particularly affected by new regulation as well as efficiency-needs. With regards to greening, the more value-based bottom-up processes (organic agriculture and short supply chains) are driven by small-scale farms and organic farming networks. On the other hand, in regulatory-driven greening the chamber of agriculture supported farmers with implementation.

The analysis shows that the chamber of agriculture is the dominant actor across both digitalisation and greening dynamics, in which it increasingly bridges the values-based and compliance-driven greening streams. Nevertheless, internal organizational structures within the chamber of agriculture present a barrier for integration of the different streams.

Overall, a weak coupling between digital trajectory and green trajectory changes is observed also shaped by the different actor groups adopting these changes. Yet, more recently, a coupling is beginning to take place in both of the digitalisation and greening dynamics described above. These are characterized by digital short supply chain platforms and the market gardening niche based more in the greening trajectory, the market gardening niche as well as farm-level precision agriculture based more in the digitalization trajectory. The coupling logic is in these cases introduced by funding mechanisms as well as efficiency logics, yet remains partial.

RQ2: How are upskilling and reskilling initiatives developing in the context of the Twin Transition?

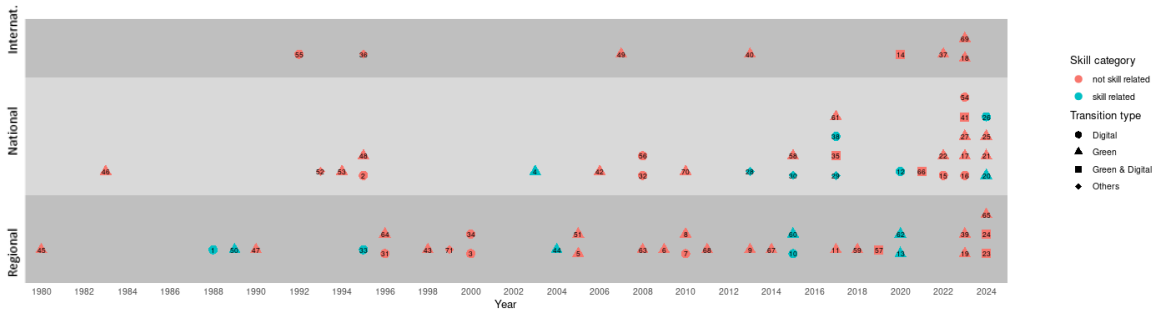

Figure 24: Transition Topology depicting institutional changes related to skill (and non-skill)-related initiatives as well as transition type across multiple spatial scales in the agriculture sector in Styria, Austria (1988-2024).

In the topology (Figure 24) of the agriculture case in Styria during the early phase between 1988 and 2010 skilling initiatives develop in parallel with the transition (pattern d). From 2010 onwards there is an increase of skill-related events (pattern d). A different pattern occurs after 2022 when most events are not skill-related (pattern c).

Description of the Patterns, Sequences and the underlying Micro-Dynamics in the Empirical Case

Between 1988 and 2010, several skilling initiatives in relation to green and digital skill occurred. The earliest skilling-related event is the conversion of the agricultural Technical College Alt-Grottenhof to organic agriculture in 1989 (Event 51) which reflects the bottom-up organic farming movement's early anchoring within the formal vocational education system. With regards to digitalisation the establishment of the Agricultural IT Club Styria (1988, Event 1) initiated by the chamber of agriculture reflects an early response to increasing documentation requirements in farm management (Interview03).
With Austria's EU accession in 1995 and the increasing mandatory documentation requirements across livestock production, digital literacy was increasingly mandated by farmers. The LFI Styria, as the adult education arm of the chamber of agriculture, responded quickly to this upskilling demand by expanding its course offering in basic courses in agricultural information technology (Event 33; Interview03).
The establishment of the Organic Centre Styria in 2004 (Event 44) a joint initiative of the chamber of agriculture and Organic Harvest Styria expanded the formal infrastructure for greening-related skilling. The centre provides a dedicated advisory, research, and training hub for organic farming in Styria. Through bringing together the chamber of agriculture and Organic Harvest Styria it is the first indication of a shared organizational arrangement that bridges the value-based and compliance-driven greening streams.

The emergence of technological advancements (e.g. GPS-guided machinery and precision farming) in the 2000s/2010s did not immediately lead to formal changes in skilling. One interview partner from the chamber of agriculture described how agricultural fairs and demonstrations at institutions such as the Landtechnikschule Mold and later the Innovation Farm Raumberg-Gumpenstein served as informal knowledge transfer channels (Interview03), where farmers encountered new technologies in practice before formal training curricula were developed. Only in 2017, did the LFI rolled out a nationwide educational campaign in Digitalization in Agriculture and Forestry (Event 38). Here courses covered topics such as precision and smart farming, cyber security as well as data and farm management.

Similarly, new compliance requirements in greening led to an increase in skilling response during the same period. One example is introduction of the restructured Pesticide License in 2015 (Event

60) the mandatory certification for pesticide use created a formal qualification requirement for all farmers using plant protection products, affecting primarily conventional farming (Interview03).

While not directly constituting skilling initiatives, the establishment of the NGO Perspektive Landwirtschaft in 2013 (Event 28) and the subsequent launch of the farm succession platform Perspektive Suche in 2017 (Event 29) reflect an emerging movement which addresses farm succession one of the most pressing labour market challenges in Styrian agriculture (Interview09).

After 2020, the patterns suggest skilling initiatives becoming less frequent, however the analysis suggests that more integrated and coordinated skilling occurred. In the market gardening stream identified in RQ1, skilling is embedded as an integral component of the transition dynamic from the outset. Examples are the online roundtables for market gardening (2020, Event 12) and the establishment of a dual study programme in market gardening (2020, Event 62; Interview02).
In addition, the Digital Action Plan Smart Farming, presented in November 2023, was the first national-level policy document to explicitly frame digital agricultural skills as a cross-cutting requirement across sustainability, climate adaptation, and competitiveness simultaneously.

Analysis of the Dynamics of Skilling Initiatives

Early skill-related events emerge in connection with both regulatory-driven digitalisation and values-based greening. From around 2015 onwards, skilling becomes more reactive, with initiatives consistently following regulatory and industry developments rather than anticipating them. Subsequently, the focus of skilling shifts towards new agricultural production models, most notably market gardening.

Similar to the pattern described in RQ1, greening- and digitalisation-related skilling followed different logics. Greening-related skilling was primarily regionally embedded and driven by the values-based organic farming movement and its associated institutions. Digitalisation-related skilling tended to follow compliance and efficiency logics.

Genuinely twin transition-oriented skilling remains largely absent, with only the most recent events beginning to couple the two dimensions. One exception is the market gardening stream, in which actors drive the parallel development of both production practices and associated skilling offers.

The LFI is the main actor initiating and implementing both greening- and digitalisation-related skilling in the Styrian agricultural case. However, similar to the pattern described under RQ1, the LFI's internal structures reproduce the separation of the two transition dynamics rather than integrating them.

ii. Nord-Est Region (LSE)

RQ1: To what extent is a Twin Transition emerging at the regional level within the institutional context of the labour market?

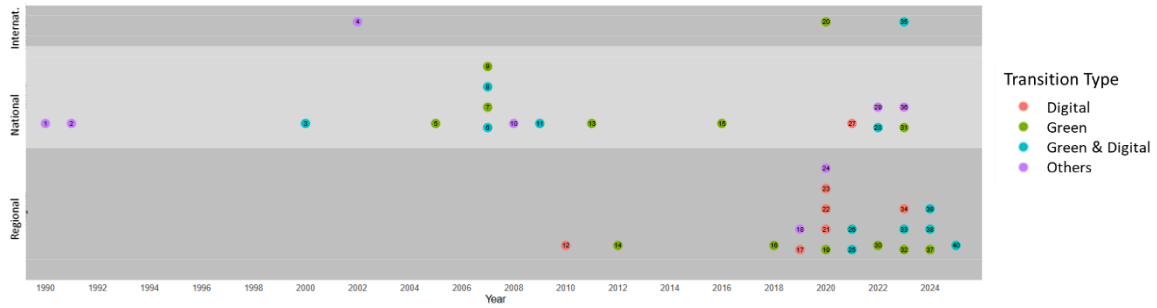

Figure 25: Transition topology depicting institutional and organizational changes related to greening and digitalisation across multiple spatial scales in the agricultural sector in the Nord-Est region, Romania (1990-2024).

In the topology (Figure 25) of the agricultural case of the Nord-Est region of Romania, we read the period from EU accession in 2007 through the mid-2010s as pattern (a) - greening-related changes clearly predominate. From the early 2020s onwards, the case shifts towards a coexistence of pattern (c) and pattern (d). Pattern (d) is concentrated on larger farms and specific event clusters rather than diffused across the regional sector.

Description of the Patterns, Sequences and the underlying Micro-Dynamics in the Empirical Case

In the agricultural case in the Nord-Est region of Romania, several institutional and organisational changes related to greening and digitalisation can be observed, which were shaped through the interactions of different actor networks across multiple governance levels.

The structural conditions for both transitions were laid in the early post-communist period, as can be derived from several documents of the European Commission. The 1991 Land Restitution Law (Event 2) returned agricultural land to former owners, fragmenting the previously consolidated cooperative system (Event 1) into a landscape of micro-farms oriented toward subsistence production. It created a dual landscape: large farms of several hundred to several thousand hectares coexisting with a persistent stratum of subsistence micro-farms, whose asymmetry conditions the reach and pace of both greening and digitalisation throughout the period. As one stakeholder described, this period saw a “disaggregation of the primary sector” correlated with similar processes in secondary and tertiary sectors, alongside an erosion of financial and human capital in rural areas. The pre-accession SAPARD instrument (Event 3) provided the first limited external push toward modernisation, while the 2002 EU visa removal (Event 4) preceded the outward labour migration patterns that interviewees consistently identify as eroding the rural workforce.

Greening-related developments at the regional level emerged primarily after Romania’s accession to the European Union in 2007 (Event 6), when the Common Agricultural Policy framework was implemented through APIA registration and direct payments (Event 7; Interview04) and the National Rural Development Programme (Event 8). Environmental conditionality became the principal vector of greening: pesticide regulation was institutionalised through Government Decision 683/2011 (Event 13), the communal manure storage platform (Event 16), cross-compliance and eco-schemes were progressively introduced, and cover crop obligations were later codified within the CAP Strategic Plan 2023–2027 (Event 32). The Farm to

Fork Strategy (Event 20; Interview01) provided a further EU-level reference. Most farmers engaged with these regulations through a compliance logic, navigating new requirements via APIA training rather than through proactive participation in environmental policy design.

Alongside this regulatory wave, a small group of early-mover farms developed organic farming as a distinct strategy. One foreign-investor practitioner described starting organic farming specifically because limited capital meant inputs could not be purchased and certified the farm a few years later (Event 14). This case illustrates that organic farming initially emerged not as a response to EU subsidies but as a capital-constrained adaptation, with EU funding access from 2009 onwards subsequently providing structural support for further investment (Interview04&09&10).

A parallel, demographically driven process gradually transformed the regional farm structure. As ageing smallholders leased their fragmented parcels to larger operators, described by one practitioner (Interview08) with the words "people grew old and because of that, they leased it out", large commercial farms of several hundred to several thousand hectares emerged alongside a persistent stratum of subsistence micro-farms. This dual structure became a precondition for both transitions: scale enables environmental management and makes precision agriculture economically viable, while micro-farms remain largely excluded from both processes.

Digitalisation followed a two-stage trajectory. From 2007 onwards, EU funding instruments such as the National Rural Development Programme (Event 8) and the Young Farmer Programme (Event 11, Interview04&09&10) supported equipment modernisation. This modernisation process relied mostly on embedded digital technologies, such as GPS, computerised controls, and sectional control on seed drills. Entering farms can thus primarily be understood as a side-effect of machinery upgrades rather than as a deliberate digitalisation strategy.

Deliberate digitalisation became visible primarily from the early 2020s onwards. Following the onset of the COVID-19 pandemic, small local producers in the Nord-Est region accelerated the adoption of digital ordering, virtual sales formats, and direct delivery systems, while at the same time building upon a greening logic based on authenticity and regionality. Among others, a digital producer-consumer platform was developed during the pandemic (Event 21), alongside online tastings and virtual sales formats during lockdown periods (Event 22). In parallel, producers started to develop their own e-commerce websites (Event 23), and the "Shelf with Local Goodies" platform linking producers to retail markets (Event 27). The Horizon Cities 2030 project (Event 19) specifically supported the Iașiul în Bucate event (Event 30; Interview01), bringing together several certified ecological, mountain-product, and traditionally attested producers. This latter again illustrates how the pandemic catalysed the bottom-up coupling between local food systems and digital channels.

In parallel, digital adoption especially at larger farms advanced through the spread of agricultural drones (Event 17), agricultural spraying drones (Event 38), and GPS-guided tractors on mid-size farms (Event 40; Interview02&05). With the implementation of the CAP Strategic Plan 2023-2027 (Event 31), horizontal scoring principles (Event 35) such as digitalisation, environment, and accessibility became increasingly embedded in funding scoring criteria. One stakeholder explained the reasons for this development in more detail: "companies were forced, if I may put it that way, to assume digitisation measures … in order to obtain the score". Hence, this illustrates how the EU funding architecture has begun to operate as a top-down coupling mechanism between greening and digitalisation at the project-design level.

In the interviews and accompanying desk research, three factors, which explain the relatively faster uptake of digitalisation compared to greening become apparent: i. equipment suppliers acted as de-facto technology transfer agents, lowering the adoption barrier through after-sales training, ii. the COVID-19 pandemic created an immediate market pressure that forced small producers to adopt digital sales channels or lose customers entirely, and iii. EU funding scoring criteria introduced a direct financial incentive to declare digitalisation commitments at the project-design stage.

At the regional governance level, according to desk research, the RIS3 Nord-Est 2021-2027 strategy (Event 25) and the Regional Development Plan Nord-Est 2021-2027 (Event 26) introduced regional priorities that were both related to green and digital transformation. However, regional strategies remained primarily framing documents, with implementation reliant on national-level funding channels. The restructuring of the LEADER porgramme (Event 36) in 2023 further centralised agricultural project funding at the national level. It thereby removed this dimension from Local Action Group portfolios while only training and entrepreneurship support measures were retained locally.

External shocks reinforced rather than reconfigured these dynamics. The Russia-Ukraine war triggered a sharp rise in fertiliser and diesel prices, the collapse of domestic grain prices through Ukrainian transit and successive drought years, culminating in farm closures, particularly in Iași county. The response of the state was reactive, providing compensatory support rather than transformative reform, leaving the underlying structural asymmetries between large commercial farms and subsistence operators intact.

Analysis of the Twin Transition Dynamics

The case shows that greening and digitalisation did not emerge as an integrated process but rather followed distinct development logics, relying on distinct actor networks and developing over different timeframes. Greening was mainly an EU-driven, regulation-led process with national agencies such as APIA mediating between EU policy and farm-level implementation. Farmers in this process engaged primarily through compliance. Digitalisation evolved instead through a more dispersed set of channels: equipment suppliers acted as de-facto technology transfer agents, EU funding scoring criteria progressively rewarded digital investments, and pandemic-driven demand for short supply chains accelerated consumer-facing digitalisation among small producers.

While the principal driver of both transitions is the EU policy and funding architecture, the latter operates via different mechanisms, namely, regulatory compliance for greening and competitive scoring for digitalisation. By making scale-dependent investments economically viable, land consolidation created the structural precondition for both processes. The latter was driven by demographic ageing and outward labour migration. The most severe barriers that were identified are the misalignment of skilling infrastructure with farm-level technological and regulatory realities as well as the persistent dual structure of regional agriculture. The latter means that large commercial farms coexist with a substantial stratum of subsistence and semi-subsistence operations that are excluded from both transitions.

In summary, the Transition Topology reveals that the twin transition in the agricultural sector of the Nord-Est region has not emerged as an integrated process but as a sequential and asymmetrical one. Notably, in this process greening and digitalisation operate predominantly through separate institutional logics. Integration between the two processes is visible in the COVID-era short supply chain platforms, farm-level precision agriculture technologies, and EU

funding scoring criteria. Yet, rather than being diffused across the regional sector, this integration is concentrated on a subset of actors who have both the capital and capacity to engage with the two agendas simultaneously,

RQ2: How are upskilling and reskilling initiatives developing in the context of the Twin Transition?

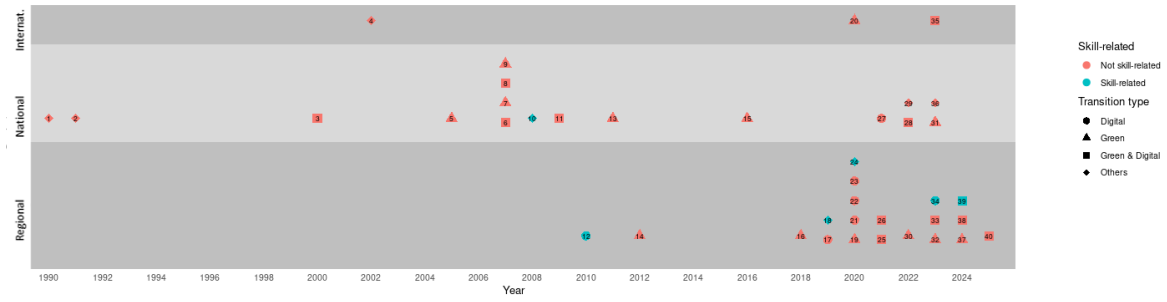

Figure 26: Transition Topology depicting institutional changes related to skill (and non-skill)-related initiatives as well as transition type across multiple spatial scales in the agriculture sector in the Nord-Est region, Romania (1990-2024).

In the topology (Figure 26) of the agricultural case of the Nord-Est region of Romania, we read the regional configuration as a coexistence of pattern (c) - skilling initiatives develop in parallel with the Twin Transition but remain poorly aligned with it - and a partial expression of the "absent or very rare" pattern, since formal skilling initiatives specifically addressing the Twin Transition are largely missing at the regional level. A secondary, sequential dynamic is also visible, in which the dismantling of agricultural vocational education from the 2000s onwards preceded the Twin Transition and removed key institutional infrastructure that might otherwise have supported coordinated skilling responses.

Description of the Patterns, Sequences and the underlying Micro-Dynamics in the Empirical Case

In the agricultural case in the Nord-Est region of Romania, skilling initiatives operate within an institutional context shaped by the long-term erosion of agricultural vocational education, fragmented programme delivery, and the dominance of informal learning channels at farm level. The most consequential institutional change for regional skilling was the gradual dismantling of agricultural vocational education from the 2000s onwards (Event 10). One stakeholder (Interview18) described this as a hasty decision taken by successive Romanian ministries, removing the secondary education link between primary schooling and higher agricultural education and creating what the same interviewee called "a missing link" between primary, secondary, and higher education. A policymaker (Interview06) recounted that their commune's agricultural professional school operated until 2007 before being disbanded due to declining enrolments, and that a subsequent attempt to establish a dual-education class failed because the minimum number of student requests could not be reached. Practitioners across the interviews described the surviving agricultural high schools as poorly resourced and disconnected from contemporary farm realities. This long-running institutional erosion preceded the Twin Transition and removed a key channel through which responsive, practice-oriented training could have been delivered.

Higher education adapted somewhat better, but with persistent lags. A practitioner (Interview02) who graduated several years ago described being taught on the U650 tractor of the communist era while modern GPS-equipped machinery was already in commercial use; another practitioner (Interview12) reported that university professors were surprised when he described the section-control seed drill technology he had encountered in his farm work. At the same time, one

stakeholder (Interview15) noted that some universities have more recently invested in digitalisation, with funding, time, and training hours allocated to introduce the concept of digitalisation in a practical way in education, suggesting that the higher education system is gradually closing the gap, primarily through its research function.

After 2020, EU-funded skilling programmes constitute the principal source of formal training in the region, but agricultural-specific provision within them remains marginal. The Human Capital Operational Programme (Event 18), the Education and Employment Programme (PEO), and the European Social Fund channel qualification courses through Local Action Groups (Event 24), training providers, and county-level employment offices. One Local Action Group manager (Interview17) described organising qualification courses for around 200 people in fields such as worker in commerce, in IT, computer operator, and home caretaker, while agricultural-specific courses involved only around 20 participants. Multiple interviewees raised concerns about the phenomenon of "course hunters" - individuals who participate in training programmes for the financial subsidy rather than for skills acquisition and which a general public respondent (Interview20) described as "a generalized hypocrisy in which we all accept … that a person has followed the 360 hours."

The National Agency for Employment and Training (Event 34, AJOFM at county level) operates within a similar funding architecture and faces structural lags in programme design. A general public respondent (Interview20) described the institution as relying on European funding for its retraining activities over the past decade, with no programme funding from the national budget, a condition the same interviewee characterised as institutional fragility. The respondent further noted that current programmes implemented through the Inclusion and Social Dignity Programme and the Education and Employment Programme are based on a needs analysis carried out around 2020, during the pandemic period, while the labour market context has since shifted with the war and the emergence of artificial intelligence. This mismatch between the timing of needs assessments and programme delivery means that publicly funded skilling initiatives systematically trail behind the transition dynamics they are intended to support.

Local Action Groups themselves provided some training through the LEADER programme, including training components within entrepreneurship support measures and young farmer programmes. A LAG manager described typical strategies financed at EUR 1–1.2 million across all measures, with individual young farmer grants of EUR 25,000–40,000 - characterised as "quite small aid". In the current 2023–2029 programming period, however, agricultural project funding was removed from Local Action Group portfolios and concentrated at the national level (Event 36), with the same interviewee (Interview19) explaining: "Now, at the moment, we no longer finance such projects because they were removed from the local level and only the measures at the national level remained." Training components within entrepreneurship and young farmer support remain at LAG level, but pure agricultural investment support is no longer accessible through this channel.

In the absence of adequate formal training, the dominant skilling mechanism in the region is informal, on-the-job learning. The skills required to operate these embedded digital technologies were largely transmitted through informal channels: supplier training upon equipment purchase (Event 12), peer exchange, and self-learning, rather than through formal education. Practitioners consistently described learning to operate new digital technologies through self-teaching, peer networks, and supplier-led training upon equipment purchase (Events 12,39). An organic farm practitioner (Interview07) preferred to professionally train his workers on the farm, through his own presence and experience, rather than rely on external courses. Equipment suppliers thus

function as the principal skills-transfer agents for digital agricultural technologies, operating outside the formal education and training system.

A more recent, emerging skilling channel is built around participatory governance arrangements anchored in the Rural Development Research Platform Association, which connects public authorities, the Romanian Academy branch in Iași, the North-East Regional Development Agency, the University for Life Sciences, and small producers. This network has organised events such as Iașiul în Bucate (Event 30), supported by the Horizon Cities 2030 project (Event 19), bringing together producers, researchers, and consumers, and represents an early platform for coordinated skill development across actor groups (Interview01). However, its reliance on project-based funding limits long-term institutional sustainability, and its reach to date is limited compared to the scale of skilling needs in the region.

Overall, skilling initiatives in the region operate within a fragmented landscape: an eroded vocational education base, EU-funded programmes that lag behind labour market realities and offer little agricultural-specific content, informal supplier-mediated training that is effective but narrow in scope, and emerging participatory networks that remain small in scale. There is no functioning dual education system in agriculture, despite repeated calls for one across actor groups, and no structured channel through which green and digital competences are developed in an integrated manner.

Analysis of the Dynamics of Skilling Initiatives

The case shows that skilling initiatives in the agricultural sector of the Nord-Est region are limited in scope, structurally lagged, and rarely integrate green and digital skill development. The principal driver of the formal skilling activity that does exist is EU funding through POCU, PEO, ESF, and LEADER, without which there would be limited agricultural training in the region. Equipment suppliers constitute the most effective skilling mechanism for digital agricultural technologies, operating through after-sales market logic rather than through public training infrastructure. Individual farmer initiative such as self-learning, family knowledge transmission, and peer exchange carries the bulk of actual skills development at farm level.

The principal barriers are the dismantling of the agricultural vocational education infrastructure, which cannot be replaced through project-based interventions of limited duration; the structural lag in policy implementation, exemplified by needs analyses conducted during the pandemic now driving programmes implemented several years later; the “course hunter” phenomenon, which undermines the effectiveness of subsidy-supported training; and the absence of a dual education system in agriculture, which would otherwise link education policy, agricultural policy, and labour market policy. Outward labour migration, identified across the interviews as a major regional concern, reinforces these barriers by depleting the human capital base on which any future skilling expansion would draw.

In summary, skilling initiatives in the regional agricultural sector develop in parallel with the Twin Transition rather than ahead of it. Moreover, they rarely combine green and digital competences within a single training pathway. The most integrated form of competence development arguably takes place informally on larger farms. In this context, practitioners describe sustainability and digitalisation as inseparable aspects of their daily decision-making. Yet, it is challenging to scale such farm-specific integration to the broader regional labour market without first reconstructing the formal skilling infrastructure in a coordinated way.

4. Conclusions

This section summarizes the main results of Task 4.2, the interpretation of the analysis of micro-dynamics underlying institutional change in regional labour market transformations, the limitations and next steps of WP4.

a. Main results

Deliverable D4.2 builds upon the conceptual and methodological approach and data basis established in D4.1. The report laid out the research design and implementation for Task 4.2, which was structured around two research questions and analysis templates including four steps distributed to the partners. The deliverable identified common patterns underlying the institutional and organisational changes mapped across the 13 cases and surfaced the underlying micro-dynamics.

The findings are structured around the two core research questions: RQ1 examines the extent to which a Twin Transition can be observed at the regional level and what drivers and barriers shape these dynamics. RQ2 examines how skilling initiatives evolve in the context of the Twin Transition and which drivers and barriers shape these processes. For RQ2 we adopt a wide understanding of skilling which considers skilling initiatives across all educational phases in line with the EU's Skills Agenda. In this manner D4.2 is able to refine the prepositions and initial finding documented under D4.1.

b. Interpretation

Building on the case-specific findings presented in Chapter 3, this section synthesises the in-depth analysis of the cross-case patterns and micro-dynamics identified across the 13 case studies with respect to the two core research questions guiding the analysis in D4.2.

Diverging Temporal Patterns of Greening and Digitalization

Across the case studies, greening and digitalisation consistently follow distinct temporal patterns. In most cases greening emerges earlier and digitalisation develops later, largely in parallel. This sequential, asymmetric pattern appears across sectors and regions, though with variations in timing, pace, and the degree to which the two transitions eventually become coupled. Examples for cases which show at least some degree of coupling are the food cases in the Vulkanland (Austria) and Val Poschiavo (Switzerland) in which a greening transition becomes explicitly linked to digitalization through a deliberate regional strategy, as well as the energy cases in Vestland (Norway) and Groot-Rijnmond (the Netherlands). Other cases, show a weaker coupling of both transitions, with institutional coupling taking place only in selected niches of the sector (e.g., agriculture case in Styria, tourism cases in Crete).

Distinct Institutional Logics driving Greening and Digitalization

The in-depth analysis reveals that the separation of greening and digitalisation is not only a matter of timing but reflects deeper differences in terms of the institutional logics, as well as the actor constellations driving them. In addition, there is also some variation regarding these drivers within each of these two transformation processes.

In particular, greening is underpinned by different institutional logics. In several cases, e.g., the food cases in the Vulkanland and Val Poschiavo and the agriculture case in Styria, greening is

driven by a values-based logic rooted in regional identity, rather than regulatory compliance or market pressures. Here, transformation is mainly driven in a bottom-up way by regional intermediaries and small-scale producers, aiming to strengthen regional value creation. In contrast, in other cases, e.g., in the food case in Crete and the agriculture case in the Nord-Est region, greening follows a predominantly compliance driven logic. In these settings, compliance-oriented greening is largely adopted by larger firms, which respond to regulatory requirements and formal standards, often integrating sustainability measures as part of mandatory reporting or certification schemes. In another group of cases, e.g., the energy case in Vestland, as well as the food and tourism case in Crete, greening is predominantly linked to efficiency logics, particularly in the context of cost reduction and waste minimization. This logic is – as elaborated below – more compatible with that underpinning the digital transition. Similar to the compliance-driven cases, efficiency-oriented greening is incentivized by public funding mechanisms and is predominantly implemented by companies to improve their organizational performance.

In contrast, digitalisation, tends to follow a predominantly efficiency- and market-driven logic, while sometimes also being linked to regulatory changes. Digitalisation processes are largely adopted by companies to reduce costs, improve operational performance, access markets, or comply with administrative requirements.

Rarely digitalisation is part of a deliberate greening process at the regional scale. While public actors also play a role in enabling funding for digitalisation, the integration of digitalisation and greening remains limited. In most cases, digitalisation serves economic and operational objectives rather than environmental ones, resulting in two largely separate transition processes. Only in a few instances, such as the food cases in Val Poschiavo and Vulkanland and the energy case in Vestland, does a stronger coupling emerge, with digitalisation directly supporting sustainability goals and regional greening trajectories.

Coupling Mechanisms between Greening and Digitalisation

While in the later stages a certain degree of coupling between greening and digitalisation is evident across most cases, the analysis shows that the coupling of greening and digitalisation is not an automatic or self-sustaining process. Due to the different institutional logics and actor groups behind greening and digitalisation, coordination and integration between both transitions remains limited in many cases. The findings therefore indicate that for meaningful coupling to occur deliberate institutional work by actors capable of bridging and aligning both domains is required.

Across the cases, different mechanisms of coupling between greening and digitalisation can be identified. First, in some cases, regional intermediary actors are able to reframe and translate digitalisation into an already existing value-based greening trajectory as for example in the case of the Vulkanland in Styria. Second, regulatory impulses at international and national levels linking both transitions can lead to processes that can be categorized as following a twin transition logic (e.g., in the energy and agriculture cases). Here linking both processes increasingly constitutes a requirement to access funding instruments at the regional level. Furthermore, Covid-19 can be described as a macro-level event which accelerated both digitalisation and greening simultaneously and led to coupling such as in the case of shortening agricultural value chains.

Despite these mechanisms, the empirical evidence suggests that greening and digitalisation frequently continue to evolve as largely separate transition processes. Where twin transition dynamics emerge, they often remain fragmented and weakly coordinated. Stronger forms of

coupling appear only where dedicated actors, institutional arrangements, or policy frameworks actively align digital and environmental objectives.

Sectoral Variation in Greening and Digitalization Dynamics

While greening and digitalisation consistently follow distinct temporal patterns across cases, sectoral uptakes and dynamics of greening and digitalisation differ. The agriculture and food sectors are characterized by an early emergence of greening-related processes and digitalisation driven by industry and regulatory requirements. In the energy and transport sector digitalisation processes occur more frequently and greening processes are more likely to be coupled to digitalisation. In the tourism sector digitalisation and greening to a certain extent are driven by industry pressures and efficiency logics, however the coupling of both greening and digitalisation appears to be less conducive as digitalisation and greening follow opposing trends in the tourism sector. Therefore, twin transition coupling is most visible in cases where sectoral characteristics create a direct functional link between greening and digitalisation such as digital traceability enabling organic certification in the agricultural sector, or smart grid management enabling renewable energy integration in the energy sector.

Reactive rather than anticipatory Skilling Trajectories

Across most cases, skilling initiatives consistently followed rather than preceded or ran parallel to the broader greening and digitalisation transitions. In few cases, skilling initiatives emerged in parallel to the transition and were proactively shaped by actor groups adapting them to regional development strategies and broader visions (e.g., the food cases in the Vulkanland and Val Poschiavo). In other cases, the disconnect between the general transition dynamics and skilling responses is particularly evident as e.g., in the case of the energy sector in Łódzkie, Poland.

Greening and Digitalisation related Skilling Dynamics

Similar to the findings regarding RQ1, greening-related and digitalisation-related skilling initiatives emerged through fundamentally different institutional logics and actor constellations across all cases, with twin transition related skilling remaining scarce overall.

Greening-related skilling was driven in several cases by the same values-based, identity-oriented actors who drove the greening transition itself. These skilling initiatives were institutionally embedded and focused on broader knowledge dissemination and identity formation rather than formal and standardized skilling credentials. Digitalisation-related skilling was driven predominantly by efficiency demands, firm-internal training programmes in large companies, and state-level or national programme initiatives. While these skilling initiatives tend to be more integrated in formal education systems and labour market credentials, the findings showed that digital skilling remained largely uncoordinated in most cases. Twin transition related skilling initiatives remain scarce. Only in a few cases, niche-specific combination of twin transition skilling takes place as for example in the case of the energy sector in Vestland. The absence of coupling between those two dynamics can also be attributed to the asymmetric patterns, diverging logics and actor groups driving skilling initiatives.

Structural Inequalities in regional Skill Formation

Across the cases, two actor groups mainly shape the skilling landscape. First, large firms consistently develop internal skilling initiatives addressing both green and digital skills, yet with an emphasis on green skills. In contrast, smaller companies lack the ability to develop and access up- and reskilling. In some cases, cluster-based skilling activities aim to close this gap.

However, the cases show a remaining structural deficiency, as such initiatives rely on external funding cycles. As a result, access to skill development remains uneven, systematically reproducing skill inequality between large and small firms and between regions with dense large-firm networks and those dominated by SMEs and micro-enterprises.

Second, universities and higher education institutions play a significant role in skilling across several cases. Nevertheless, these skilling initiatives target future graduates and workforce rather than up- and reskilling the existing workforce. Therefore, these patterns suggest that immediate skilling needs of existing employees remain underserved. In addition, universities and higher education institutions are characterized by varying engagement with regional transition dynamics. Whereas in some cases these organizations proactively address skilling independent and before explicit industry demand, in other cases the skilling response is more reactive.

Taken together, these findings suggest that regional skill formation is characterised by structural inequalities in both access and provision. Existing skilling arrangements tend to favour large firms and future labour market entrants, while the training needs of smaller firms and incumbent workers remain comparatively underserved.

Governance Barriers to anticipatory Skilling

As touched upon, several barriers exist with regards to skilling initiatives in the context of regional labor markets. First the lag between transition dynamics and the observed skilling response, underlines governance challenges in anticipating skilling needs. Second the uncoordinated response across multiple spatial scales and actor groups evident in many cases further compounds these challenges. A related barrier is the structural misalignment between where relevant skilling instruments are located (i.e., predominantly at the national or state level) and the needs of regional labor markets. In this regard, the findings underline the need for skill formation policies to take into account regional transition dynamics which lead to diverging labor market demands.

These governance challenges are particularly pronounced in sectors and regions dominated by SMEs. While larger firms often possess the resources and organisational capacity to up- and reskill their workforce internally, SMEs frequently lack the financial and human resources required to do so. Furthermore, the broader labour market governance context shapes the effectiveness and continuity of skilling responses. Cases such as the agriculture sector in the North-East Region and the Cretan case studies reveal institutional weaknesses in the provision of training and workforce development. In these contexts, skilling initiatives often depend on temporary external funding mechanisms, limiting their long-term sustainability and reducing the capacity for anticipatory skill formation.

c. Limitations

The findings presented in D4.2 are subject to some methodological and data-related limitations.

First, as mentioned in D4.1 and made transparent in the tables at the beginning of each results' su-chapter, data saturation varies across case studies, reflecting differences in the availability of documentary evidence and interview partners. While some cases are based on a higher number of interviews (up to 20), others rely on a smaller set of interviews (only four) or none at all but have therefore been complemented by more extensive documentary sources. This variation in the composition of the evidence base affects the comparability of findings across cases and should

be taken into account when interpreting cross-case patterns but also for assessing the robustness of the findings for individual cases.

Second, the case comparability, while covering five sectors and multiple regional and national contexts, is constrained by the fact that cases were selected by project partners based on contextual relevance and availability. While this introduces a degree of selection bias that should be considered when interpreting cross-case patterns, it is also – as already argued in more detail in D4.1 – to some extent necessary in order to ensure sufficient case-specific depth and access to relevant actors and data sources.

Third, the selection of events follows an interpretive, process-analytic understanding of relevance and is guided by their significance for reconstructing the regional process trajectory, rather than by the frequency of their mention. As such, event selection is necessarily perspective-dependent and shaped by both the accounts of interviewees and the researchers' analytical interpretation. Triangulation between interviews and documentary sources has already been applied to support and contextualize the reconstruction. However, in some instances this could be further deepened and systematized to enhance the transparency and robustness of the resulting event sequence.

In order to address these limitations related to data availability, interpretation, and generalisability, communicative validation will be conducted in the focus groups.

d. Further work

The findings and micro-dynamics underlying institutional change presented in D4.2 provide the foundation for Task 4.3. In task 4.3, focus groups will be conducted with regional stakeholders to discuss governance challenges and opportunities based on the findings from the topological analysis in Task 4.2. They will thus also serve to validate the findings from Task 4.2 and address remaining data gaps. Furthermore, the insights developed in D4.2 build a basis for the case comparison and synthesis in Task 4.4, contributing to the formulation of policy and governance recommendations.

In addition to their contribution to WP4, the findings presented here offer several important inputs for other work packages. This concerns three aspects in particular: First, the in-depth case studies identify mechanisms and contextual factors that can help explain the growing regional disparities observed in the quantitative analyses in WP1 and WP2. By reconstructing regional development processes over time, they provide insights into how such patterns emerge and become reinforced. Second, our findings show how inequalities can emerge and persist over time, e.g., between particular actor groups in the region. As such, the findings contribute to ongoing work in WP3 and WP6 on social inclusion and exclusion dynamics (in particular Task 3.2). Third, the case studies presented here, can help to identify and contextualize best-practice regional initiatives and training programmes. This can serve as a valuable starting point for WP6's work on identifying and assessing best practices for the design of upskilling and reskilling programmes.

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Annex 1: Template for D4.2: Identification of patterns of institutional change and their micro-level drivers

RQ 1: Twin Transition

To what extent is a Twin Transition emerging at the regional level within the institutional context of the labour market? What are the drivers and/or barriers to this?

RQ1_Step 1: Identification of Patterns / Sequences

Typical patterns/sequences relevant to RQ1:

- Greening-related changes clearly predominate (pattern a)
- Digitalisation-related changes clearly predominate (pattern b)
- Both types of changes occur, but predominantly separately (pattern c)
- Both types of changes occur in an integrated manner (pattern d)

Please identify which of these patterns are visible in your case. This can be done based on the first topology for your case in D4.1.

Note:

- Combinations or sequences of patterns may occur (e.g. one pattern emerging first, followed by another).
- Differences may also exist across spatial levels; however, the primary focus should be on the **regional level**.

RQ1_Step 2: Description of the Patterns, Sequences and the underlying Micro-Dynamics in the Empirical Case

Describe the identified pattern(s) in your specific case and outline the relevant key events.

Then describe in detail the **micro-dynamics at the actor level** that underlie the identified patterns.

Note: The primary focus should be on the **regional level**. Developments at other spatial levels may be included where they help to explain the observed patterns or sequences.

It is easier to first describe what happened (the key events) and then move towards describing how and why things happened (the micro-dynamics) The links between events documented in the data structure template provide a useful starting point for reconstructing the underlying micro-dynamics.

You may find the following guiding questions helpful to structure your description:

- Which actor groups initiated greening- and digitalisation-related events, and what were the underlying drivers or mechanisms?
- To what extent do similar or different micro-dynamics underlie the two processes? Are there identifiable coupling moments or events, and which actors or conditions enabled them?

- Where greening and digitalisation are linked, what mechanisms and actor constellations facilitated these synergies? Did one process enable or accelerate the other?
- How did developments at higher spatial levels shape these dynamics, and how were they interpreted or adapted at the regional level? Are there indications of deliberate local reinterpretation or reshaping of external impulses by regional actors?

RQ1_Step 3: Analysis of the Twin Transition Dynamics

Based on the description in Step 2, derive an answer to RQ1. Compared to Step 2 this should be written more like a brief analytical synthesis explaining the twin transition pattern that emerged and its main drivers and barriers.

You may find the following guiding question helpful to formulate this section:

- Based on the identified micro-dynamics, what are the main drivers, barriers, and consequences of the integration of greening and digitalisation at the regional level?

RQ1_Step 4: Mapping Micro-Dynamics / Activities in the Topology

Define which **connections (temporal links between events)** could be visualised in the topology in the context of this research question in order to make the identified micro-dynamics visible.

Alternatively, you may identify so-called **"streams"**, i.e. groups of related events that are connected by shared micro-dynamics.

We can help you to visualise these links or streams in the respective topologies afterwards.

RQ2: Skilling Initiatives

How are upskilling and reskilling initiatives developing in the context of the Twin Transition? What are the drivers and/or barriers?

RQ2_Step 1: Identification of Patterns / Sequences

Typical patterns / sequences:

- Changes in the form of reskilling and upskilling initiatives occur only later, after institutional change driven by greening and/or digitalisation has already taken place in the labour market context (pattern a).
- Skilling initiatives precede the transition (pattern b).
- Skilling initiatives are almost entirely absent or very rare (pattern c).
- Skilling initiatives develop in parallel with the transition (pattern d).

Please identify which of these patterns are evident in your case. This can be done based on the second topology in D4.1.

Note:

- Combinations or sequences of patterns may also occur (e.g. one pattern emerging first, followed by another).
- Differences may exist across spatial levels; however, the primary focus should be on the **regional level**.

RQ2_Step 2: Description of the Patterns, Sequences and the underlying Micro-Dynamics in the Empirical Case

Describe the identified pattern(s) in your specific case and outline the relevant key events.

Then describe in detail the **micro-dynamics at the actor level** that underlie the identified patterns.

Note: The primary focus should be on the **regional level**. Developments at other spatial levels may be included where they help to explain the observed patterns or sequences.

It is easier to first describe what happened (the key events) and then move towards describing how and why things happened (the micro-dynamics).

The links between events documented in the data structure template provide a useful starting point for reconstructing the underlying micro-dynamics.

You may find the following guiding questions helpful to structure your description:

- Which actor groups initiated upskilling and reskilling initiatives, and what were their motivations or constraints? Through which mechanisms did these initiatives emerge or fail to emerge?
- How can the temporal patterns identified in Step 1 be explained? Why did skilling initiatives emerge late, in parallel, precede, or remain absent in relation to broader greening and digitalisation dynamics?
- Do skilling initiatives responding to greening and those responding to digitalisation follow different logics, actor constellations, or mechanisms, or are they initiated by similar drivers?
- How did national or European-level policies, funding schemes, or qualification frameworks influence the emergence (or absence) of regional skilling initiatives, and how were these translated or adapted to the regional level?
- How are skilling initiatives shaped by the broader institutional context of the labour market (e.g. education and training systems, collective bargaining structures) in your case study region or country?

RQ2_Step 3: Analysis of the Dynamics of Skilling Initiatives

Based on the description in Step 2, derive an answer to RQ2. Compared to Step 2 this should be written more like a brief analytical synthesis explaining the re- and upskilling patterns that emerged and their main drivers and barriers.

You may find the following guiding question helpful to formulate this section:

- Based on the identified micro-dynamics, what are the main drivers, barriers, and consequences for the development of upskilling and reskilling initiatives in the context of the regional labour market?

RQ2_Step 4: Mapping Micro-Dynamics / Activities in the Topology

Define which **connections (temporal links between events)** could be visualised in the topology in the context of this research question in order to make the identified micro-dynamics visible.

Alternatively, you may identify so-called **"streams"**, i.e. groups of related events that are connected by shared micro-dynamics.

We can help you to visualise these links or streams in the respective topologies afterwards.

Annex 2: The Consortium

Short name	Full name	Homepage	Logo
HVL	Western Norway University of Applied Sciences	https://www.hvl.no/en/	
BOKU	BOKU University	https://boku.ac.at/en/	
LSE	London School of Economics	https://www.lse.ac.uk/	
UoC	University of Crete	https://www.uoc.gr/en/	
UW	University of Warsaw	https://en.uw.edu.pl/	
UU	University of Utrecht	https://www.uu.nl/en	
FHNW	University of Applied Sciences and Arts Northwestern Switzerland	https://www.fhnw.ch/en/	
BFI Wien	Berufsförderungsinstitut Wien	https://www.bfi.wien/	
Simplon	Simplon.co	https://www.simplon.co/	
MOP	Municipality of Platanias	https://www.platanias.gr/en/	

Annex 3: Project Summary

SkillResilience4EU - Resilience through re-skilling and upskilling for European labour markets in transition.

The twin transition (defined as the coexistence and interplay of the green and digital transitions) has enormous impacts on European labour markets. Because the green and digital transformations can feed into, facilitate, or hinder each other, it has been difficult to predict how labour markets will absorb and respond to changes and disruptions in employment conditions, skill needs and job availability and mobility. Other ongoing global challenges and macro-economic events, like the COVID-19 pandemic, also contribute to a profound reshaping of labour markets in Europe. New sectors emerge, existing sectors need to adapt and transform. New skills need to be developed or need to be transferred from other industries. Regions and sectors need to narrow labour market and skill mismatches to minimise the costs and to maximise the benefits of job destruction and job creation processes.

Different sectors and regions are affected in varying ways and intensities, either by green or digital transitions, or the combined impact of the twin transition. This inequal distribution of job creation and destruction processes may favour or leave behind places, sectors, and socio-economic groups and may threaten social cohesion and inclusion. The institutional and policy context needs to become more flexible and responsive to cope with the ongoing transformations and narrow down the labour market mismatches. Tailored and cost-effective policies and programmes for reskilling and upskilling, in particular for the most vulnerable and left-behind socio-demographic groups and places, need to be developed together with policy makers, VET providers, unions, public authorities, and other decision makers.

Funded by Horizon Europe, the European Union's Framework Programme for Research and Innovation, SkillResilience4EU will introduce a novel conceptual framework to describe and understand the impacts of the twin transition on European labour markets and will investigate the complex mechanisms, dynamics, and challenges that regions and institutions undergo by exploring selected sectors (tourism, food, transport, agriculture, and energy). The project will develop a management tool for policy makers to support them in managing labour markets in transition with recommendations for policy scenarios. SkillResilience4EU will also map and evaluate educational and training programmes for upskilling and re-skilling and will deliver recommendations and practical resources to support individuals and employers with specific focus on career guidance and development.

To achieve this ambition, the SkillResilience4EU consortium unites higher educational institutions (Western Norway University of Applied Sciences, Utrecht University, London School of Economics, University of Warsaw, University of Natural Resources and Life Sciences in Vienna, University of Crete, North-Western Switzerland University of Applied Sciences) one vocational training institute (BFI), one private training organization (Simplon.co) and a local public authority (Municipality of Platanias). The partners cover a whole range of expertise: economic geography, innovation studies, regional development, sustainability transitions, qualitative research, institutional research, policy research, labour and behavioural economics, education, arts and design, social inclusion, VET and lifelong learning. Coordinated by Western Norway University of Applied Sciences, the project was launched on 1st January 2025 and will run for 3 years.