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The Impact of Artificial Intelligence on Sustainable Regional Innovation Ecosystems and Participation

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ABSTRACT

This study explores the transformative role of artificial intelligence (AI) within the context of Regional Innovation Ecosystems (RIEs) (Markkula and Kuhne, 2015; Salminen et al., 2022), Smart Specialisation Strategies (RIS3) (Asheim et al., 2019), and the European Union's Mission on Adaptation to Climate Change. Building upon ten empirical cases from nine countries in the Baltic Sea region, the research examines AI's potential to enhance sustainable development, climate resilience, and inter-regional cooperation (Tukiainen et al., 2020, Takala et al., 2012; 2022; 2024). While the literature on regional innovation emphasizes governance models, stakeholder engagement (Ouden, 2012), and impact assessment, the specific contributions and limitations of AI within these frameworks remain underexplored. This study aims to fill that gap by analyzing the integration of AI across various components of regional development strategies. AI offers substantial benefits in climate adaptation through enhanced data processing capabilities. It improves climate modeling and forecasting by analyzing vast datasets from satellites, sensors, and historical records, enabling more accurate predictions of extreme weather events and strengthening early warning systems. The benefits of AI integration include increased speed and efficiency in innovation processes, greater accuracy in modeling and assessments, enhanced foresight through pattern recognition, optimized resource allocation, and scalable solutions that can address both local and global challenges. In conclusion, AI holds significant potential to accelerate sustainable regional innovation, smart specialisation, and climate adaptation. However, realizing these benefits requires a careful balance between technological advancement, ethics and social responsibility (Senge, 1990).

Keywords: Artificial intelligence (AI), Human systems, Smart specialisation strategies (RIS3), Regional innovation ecosystems (RIEs), Climate adaptation/climate resilience, Climate governance, Participatory development, Ethics, Sustainable development, Circular economy

INTRODUCTION

The pursuit of sustainable development within modern governance structures requires sophisticated tools capable of managing complexity, vast datasets, and multi-scalar cooperation. Regional Innovation Ecosystems (RIEs) and Smart Specialisation Strategies (RIS3) traditionally emphasize organizational design, human factors and collaborative networks to drive economic

transformation. This necessitates an effective integration of human capabilities—including cognitive ability and team dynamics—into system design, a principle central to Human Systems Integration. However, the growing technological capacity of artificial intelligence (AI) presents both unprecedented opportunities and significant theoretical challenges for these established regional frameworks, particularly in critical areas like climate adaptation and mitigation.

This research investigates the transformative role of AI within RIEs and RIS3, specifically examining its potential to enhance sustainable development, climate resilience, and inter-regional cooperation across the Baltic Sea region. While traditional innovation literature emphasizes governance models and stakeholder engagement, the practical contributions and limitations of integrating AI into these strategies remain largely unexplored. To address this gap, this study analyzes how robust governance and comprehensive data transparency —establish the necessary institutional foundation for responsible and effective AI deployment in achieving ambitious regional climate targets. AI integration must be carefully managed to ensure that human agency, ethical oversight, and inclusive governance remain central to delivering equitable and resilient regional futures.

THEORETICAL FRAMEWORK

AI as an Enabler of Sustainable RIEs

The literature on regional development stresses that RIEs and RIS3 must foster continuous co-evolution and strengthen co-creation competencies among ecosystem partners to ensure competitiveness. In this context, AI is emerging as a powerful catalyst capable of accelerating both innovation processes and complex climate governance. The benefits of AI integration include increased speed and efficiency in innovation, greater accuracy in modeling, enhanced foresight through pattern recognition, and optimized resource allocation, providing scalable solutions to local and global challenges (Bullock et al., 2022; 2024).

AI's analytical strength is particularly salient for climate resilience and adaptation, a key component of the European Union's Mission on Adaptation to Climate Change. AI enhances data processing capabilities, improving climate modeling and forecasting by analyzing vast datasets from satellites, sensors, and historical records. This capability allows regions to strengthen early warning systems and generate more accurate predictions of extreme weather events. Furthermore, AI informs the development of adaptive infrastructure, such as smart energy grids, and supports the optimization of critical resources, including water, energy, and land. In the LULUCF (Land Use, Land-Use Change, and Forestry) sector, AI can enhance carbon capture through predictive modeling and aid ecosystem conservation efforts.

In the sphere of collaboration, AI facilitates strategic matchmaking by analyzing the needs, strengths, and competencies of various regional partners, while also lowering communication barriers through support for multilingual knowledge-sharing platforms and real-time translation. AI-driven tools can also enhance the Entrepreneurial Discovery Process (EDP) by delivering

market trend analysis, simulating policy outcomes, and identifying niche areas for specialization, thereby guiding strategic decisions within the RIEs. Overview of benefits, see Table 1.

Table 1: Benefits of AI integration in regional governance and climate action.

Area of Impact	Specific Benefits of AI Integration
Climate Adaptation & Modelling	Enhances data processing capabilities for climate adaptation. Improves climate modelling and forecasting by analysing vast datasets (satellites, sensors, historical records). Enables more accurate predictions of extreme weather events and strengthens early warning systems. Supports optimization of critical resources (water, energy, land). Informs the development of adaptive infrastructure, such as smart energy grids. Aids in ecosystem conservation and enhances carbon capture through predictive modelling.
Innovation & Collaboration	Facilitates partner identification and strategic matchmaking by analysing regional strengths, competencies, and innovation needs. Supports multilingual knowledge-sharing platforms and provides real-time translation, lowering communication barriers. Enhances the Entrepreneurial Discovery Process (EDP). Delivers market trend analysis, identifies niche areas for specialization, and simulates policy outcomes to guide strategic decisions.
Systemic Efficiency	Results in increased speed and efficiency in innovation processes. Provides greater accuracy in modelling and assessments. Offers enhanced foresight through pattern recognition. Optimizes resource allocation. Provides scalable solutions that can address both local and global challenges. Helps navigate the complexity inherent in multi-stakeholder ecosystems and climate governance.
Participatory Processes	Augments human-centric approaches by analysing qualitative data from stakeholder workshops. Identifies dominant themes and offers real-time facilitation support. Supports the creation of targeted communication materials to tailor messages to different audiences.

Human Factors, Participation, and Ethical Risks

Despite the technological advantages, the integration of AI must adhere to human principles, ensuring that systems are human-centric and sustainable. The experts strive to optimize total system performance and minimize life-cycle costs by ensuring human considerations are integrated throughout the system lifecycle, often resulting in cost avoidance and improved safety.

In participatory processes, AI augments human-centric approaches by analyzing qualitative data from stakeholder workshops, identifying dominant themes, and offering real-time facilitation support. However, the core challenge is balancing effective software and hardware solutions with human-friendly implementations. AI cannot replicate human intuition, creativity, or value-based judgment, all of which are essential for strategic and participatory development.

Several disadvantages must be addressed for ethical and equitable adoption. High initial costs for infrastructure and skilled personnel can impede AI adoption, especially in regions with restricted resources. Furthermore, the reliability of AI output is dependent on the quality of data input; biased or incomplete data can lead to flawed outputs. Ethical concerns, including algorithmic bias, lack of transparency, and the "black box" nature of many AI systems, necessitate robust oversight and inclusive governance mechanisms. Risks such as job displacement, cybersecurity threats, and the potential widening of the digital divide between technologically advanced and under-resourced regions must also be mitigated.

Table 2: Disadvantages and ethical risks of AI integration.

Category of Risk	Specific Disadvantage or Ethical Concern
Implementation & Access	High initial costs for infrastructure and skilled personnel. Can impede adoption, especially in less developed regions. Risk of widening the digital divide between technologically advanced and under-resourced regions.
Data and Reliability	Reliability depends heavily on data quality; biased or incomplete data can lead to flawed outputs.
Ethical and Governance	Ethical risks include algorithmic bias and lack of transparency. Concerns over the "black box" nature of many AI systems. AI cannot replicate human intuition, creativity, or value-based judgment, which are essential in participatory and strategic processes
Societal and Environmental	Risks such as job displacement. Cybersecurity threats. Environmental impact of energy-intensive AI systems.

METHODOLOGY: THE CARBON DISCLOSURE CASE

Building upon ten empirical cases from nine countries in the Baltic Sea region, this paper utilizes a qualitative case study approach (Yin, 1989), focusing on carbon discloser project in Southern Finland, as a rich source of empirical evidence to illustrate the necessary institutional and strategic groundwork required for the successful implementation and governance of advanced data and AI systems in regional climate work. While this case may not explicitly deploy large-scale, generative AI, its systematic approach to data collection, inter-jurisdictional collaboration, and financial transparency—as required for high-level Carbon Discloser projects States and Regions disclosure—establishes the foundational components (Governance, Data, Capacity) that any sustainable AI strategy must be built upon.

The analysis draws primarily from the detailed strategic evidence prepared for Carbon Discloser Project reporting, which mandates the quantification and verification of data across key modules like governance, assessment, targets, planning, and actions. We used the key data sources, which include:

1. **Systematic Greenhouse Gas Inventory as AI Data Stream:** The region utilizes standardized emissions data verified by the Finnish Environment Institute together with Climate watch. This digital platform provides the consistent, clean data necessary for AI-driven modeling and monitoring.
2. **Governance and Capacity as AI Oversight and Talent:** Documentation confirming political integration and the role of 'talent sources' ensures the necessary scientific and ethical oversight and human capacity for managing advanced technology.
3. **Task Force on Climate-related Financial Disclosures as AI Risk Input:** Evidence of systematic risk assessment (Adaptation Plan, Climate Watch risk maps) and the strategic allocation of funding demonstrate alignment with the Task Force on Climate-related Financial Disclosures principles, which is critical for providing economic context for AI-driven decision-making.

Together, these components create an integrated foundation for data-driven climate governance. By combining verified emissions data, institutional oversight, and risk-informed financial alignment, the region establishes a robust framework that enables transparent monitoring, informed policy design, and AI-supported decision-making. This integrated approach ensures that technological innovation is effectively linked to sustainability objectives, forming a strong basis for the subsequent results and analysis.

RESULTS: PREREQUISITES FOR AI INTEGRATION IN EUROPEAN REGIONAL GOVERNANCE

The empirical analysis of regional strategies, as captured through comprehensive climate disclosure frameworks, reveals four critical, interdependent pillars that define a European region's readiness to

successfully and ethically integrate Artificial Intelligence (AI) into its Sustainable Regional Innovation Ecosystems (RIEs) and climate governance structures. These findings, extrapolated from regional practices, provide a necessary roadmap for jurisdictions aiming to leverage AI to accelerate their climate goals.

Institutionalizing Political Commitment and Human Capacity

A fundamental prerequisite for utilizing AI effectively is the existence of robust Multi-Level Governance structures that can translate high-level political objectives into coordinated operational actions. Regions must formally integrate ambitious targets, such as carbon neutrality goals, into their highest strategic planning documents to demonstrate that the effort is comprehensive, institutionalized, and long-term, rather than dependent on a single political cycle or entity. This strategic alignment requires active coordination across various administrative levels, including national, regional, and municipal governments, a crucial element of Multi-Level Governance that carbon discloser consistently assesses.

Crucially, this system must address the demands of Human Systems Integration, recognizing that AI cannot replace human intuition or ethical judgment. Therefore, regions must systematically invest in their talent ecosystems to ensure an adequate supply of "green talent" capable of managing, designing, and overseeing AI systems. By integrating sustainable development into curriculas across all fields, regions build the capacity needed for implementation actions across sectors like energy efficiency and sustainable construction. Furthermore, inclusive governance requires broad societal engagement, often achieved through collaboration with civil society and non-governmental organizations, which contributes directly to social equity and intergenerational climate justice.

Establishing Data Standardization for Enhanced Foresight

The reliability and effectiveness of AI in areas like climate modeling and resource optimization are entirely dependent on the quality of data input. Therefore, a core result observed in leading regions is the establishment of centralized, transparent data management systems that standardize climate information. Regions must ensure that GHG emissions data (GHG Inventory), along with information regarding risks and climate actions, are collected and maintained systematically using verifiable methodologies aligned with national standards. This transparency, often managed via a publicly accessible climate watch service, not only improves the measurement, monitoring, and prioritization of climate work but also establishes the clean, consistent datasets essential for training reliable AI models.

This standardized data is foundational for advancing regional foresight and risk management. Regions must conduct systematic Climate Risk and Vulnerability Assessments that identify specific physical hazards (e.g., flooding, heatwaves) and manage transition risks associated with the shift away from carbon-intensive economies. AI offers substantial benefits in this

area by analyzing vast datasets to strengthen early warning systems and improve climate modeling accuracy. Publicly disclosing these risk assessments and corresponding risk maps is a necessary step that proves awareness and allows for the integration of resilience planning into master/development planning.

Mobilizing Strategic Finance and Augmenting Innovation

Sustainable regional innovation relies on the ability of regional governance to proactively mobilize and channel public and private capital toward the green transition. Results show that regions successfully preparing for this shift establish explicit institutional mechanisms—such as dedicated EU liaison offices or strategic innovation funds—to secure and coordinate external funding, including competitive EU funds. Critically, public finance is strategically allocated, often through innovation projects, to fund research and development (R&D) and channel investment directly toward circular economy innovations and green business development. This strategic allocation proactively manages Transition Risk by funding the creation of cleaner, sustainable economic structures.

AI significantly enhances this innovation ecosystem by supporting the Entrepreneurial Discovery Process (EDP), aiding strategic decisions by delivering market trend analysis, identifying niche areas for specialization, and simulating policy outcomes. Furthermore, by supporting high-value industrial mitigation actions, such as Carbon Capture and Carbon Utilization projects, regions create measurable economic opportunities. This focus on commercializing innovation, often supported by incubation events or startup ecosystems, establishes the region as a global solution provider, capable of exporting expertise and attracting investment.

Implementing Adaptation Through Ecosystem-Based Solutions

To build resilience, regions must formalize their commitment to adaptation, which requires collaboration and reporting on resilience pathways. The evidence suggests that effective adaptation moves beyond planning to concrete, sector-specific actions, frequently utilizing Ecosystem-based Adaptation measures. In regions dominated by rural and forest resources, adaptation involves scientifically guided management of the Land Use, Land-Use Change, and Forestry (LULUCF) sector. This includes utilizing advanced research infrastructure to inform sustainable forestry practices and developing Climate Smart Agriculture practices to protect key economic sectors like food production from physical risks such as drought and extreme precipitation. Water security, managed through multi-stakeholder catchment area governance bodies, relies on solutions, such as wetland restoration, to enhance water retention and provide natural buffers against flood risks. By embedding these actions in collaborative, scientifically supported initiatives, regions ensure their adaptation strategy is both verifiable and effective in preparing for escalating climate variability.

DISCUSSION AND CONCLUSION

The analysis of AI integration within regional strategic frameworks, supported by empirical evidence from multi-level governance models, confirms that Artificial Intelligence holds significant potential to accelerate sustainable regional innovation, smart specialisation, and climate adaptation across Europe. However, realizing these substantial benefits requires a prerequisite institutional maturity—a necessity for any region aiming to leverage technology while upholding principles of human expertise and experience.

Firstly, technological acceleration is entirely contingent upon a foundational commitment to governance and data transparency. For European regions, aligning climate strategy with rigorous international reporting frameworks, such as the carbon disclosure, provides the necessary mechanism for institutionalizing action and ensuring accountability.

This systematic process forces the standardization and collection of climate data (emissions, risks, and actions), which is the essential clean input required for reliable AI modeling, forecasting, and resource optimization. Furthermore, the political commitment to transparent disclosure validates the region's efforts in the eyes of investors and international partners, improving the chances of securing green finance.

Secondly, AI serves as a powerful strategic tool for both mitigation and adaptation, directly supporting mandates like the EU Mission Adaptation to Climate Change. In adaptation, AI's enhanced data processing capabilities improve climate modeling and forecasting, enabling more accurate predictions of extreme weather events and strengthening early warning systems for physical risk management. In mitigation, AI helps RIEs achieve ambitious climate targets by supporting the optimization of critical resources and aiding in ecosystem conservation and enhanced carbon capture through predictive modeling. Beyond climate metrics, AI facilitates seamless cross-border collaboration and strategic matchmaking by analyzing regional strengths and lowering communication barriers through multilingual support, which is vital for European inter-regional cooperation and the Entrepreneurial Discovery Process (EDP).

Finally, the success of AI integration in any RIEs hinges on maintaining a careful balance between technological advancement, ethics and social responsibility. Regions must proactively address the ethical risks inherent in AI, such as data bias, lack of transparency ("black box" issues), and the risk of widening the digital divide, particularly in less developed areas. This demands robust ethical oversight and inclusive governance mechanisms. By actively fostering participatory processes and investing in capacity building (talent and expertise), regional authorities ensure that human agency and value-based judgment remain central, safeguarding that AI ultimately contributes to equitable and resilient regional futures across the European landscape.

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