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Enabling far-reaching living labs through regional Digital Twins

HS5.7 - Multi-scale water-energy-food-environment (WEFE) nexus planning:
from research to practice in managing socio-economic, climatic, and technological change

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Abstract

- The current and future landscape of our societies is predominantly governed by urgent and interconnected resilience challenges such as **climate change adaptation**, **resource efficiency** and **sustainable WEFE nexus management**. To overcome those challenges, the European Union (EU) has set the blueprints of transformational changes with the European Green Deal, that builds on **research and innovation** to meet the objectives. Despite advances in the field, the **uptake pace** of relevant innovations is often **hindered** by the **narrow communication paths among research, public administration and citizens** -who are the end beneficiaries.
- This work utilizes the capabilities of **Digital Twins (DT)** to connect **hard and soft sensors** with **environmental and infrastructure models at regional scale**, to create a central hub for related data and knowledge to be turned into action, in a **co-creation process**. By building on existing data driven platform initiatives by the Ministry of Environment and Energy and the Decentralized Administration of Attica, we build the DT of the Region of Attica to provide: (i) **access to relevant datasets** (environmental, climatic, uses of resources etc.), (ii) **access to relevant climate adaptation services** (e.g. climate services, services to farmers, services to municipalities), (iii) **links to local and regional Communities of Practice (CoP)** and (iv) **a repository for demonstrations of climate adaptation innovations** within the region.
- This **knowledge collaboration scheme** forms a living lab constellation that allows rapid and far-reaching **sharing, accumulation, transformation, and co-creation of knowledge** among the administration parties and local case studies' stakeholders. Like ancient sailors who used constellations to navigate along route, our modern societies can use the living lab constellations of the regional DT to **chart evidence-based pathways towards climate resilience and sustainable WEFE management**. This dynamic and expandable ecosystem aims to speed up the introduction of climate adaptation innovations, connect knowledge and **bring research closer to practice** by allowing for a **re-wiring of culture**, where science and co-creation are perceived as necessary for successful policy making.

Introduction

Sustainable Water-Energy-Food and Environment system management is essential for the well-being of societies, economic growth and the resilience of ecosystems, at local and global level – especially in the face of climatic challenges and population growth. Viable technology options towards meeting SDGs exist, yet their uptake and integration to sustainable adaptation pathways requires more intuitive knowledge sharing and co-creation synergies between research, private, and public stakeholders (TEC, 2021). The **European Environment Agency (2021)** identifies that, the **efficiency of regional policies** and adaptation pathways may prove ineffective due to limited knowledge of administrative parties over available technologies and innovations, despite novel frameworks designed to assist regional stakeholders (re-)design resilient circular strategies (see e.g. Bouziotas et al, 2023). EEA further notes that **financial barriers** may arise from the limited understanding of stakeholders over the potential economic and environmental benefits of such technologies, ultimately hindering the willingness to invest in relevant initiatives. On top of the latter, **societal barriers** may also arise, at local level, due to limited knowledge by the citizens (end-users) which affects the positive response over relevant technologies, as surveys suggest (Smith et al., 2021).

Survey on societal acceptability for circular solutions (water re-use)

	Knowledge : 2.21 ₅	Positive emotion : 3.24 ₅	Willingness to pay more : 2.26 ₅
	Knowledge : 2.64 ₅	Positive emotion : 3.62 ₅	Willingness to pay more : 2.51 ₅
	Knowledge : 2.43 ₅	Positive emotion : 3.38 ₅	Willingness to pay more : 2.30 ₅

Regional Digital Twins to support evidence-driven regional adaptation pathways: The case of Attica DT

The Attica region, Greece



- Includes the Athens capital
- Area: 3,800 km²
- Population: 3,7 million (9,6 million inhabitants & tourists annually)
- Typical Mediterranean region

Challenges

- Conflicting demands agriculture-environment
- Tourism intensifies competing demands
- Groundwater over-use ↑ salinity ↓ yields
- High temperatures / reduced rainfall
- Increased energy consumption for cooling
- Reduced air quality
- Prone to flash floods
- Particularly in densely populated areas

The Attica DT



Goal: **Regional integration solution for sharing, accumulation, transformation, & co-creation of knowledge** among the administration parties, technology providers and the local case studies' stakeholders – focused on regional challenges.

Hub for far-reaching demonstration of innovations

Athens Municipal Plant Nursery									
Video	Weather		PLC Data			Plots			
Timestamp	Temperature tank 5	L11 (gpl) membrane tank 53	DO ppm L100 aeration tank 4A	DO ppm anoxic tank 3	MLSS SOLID mg/l membrane tank 5	MLSS SOLID mg/l membrane tank 4A	DO ppm anoxic tank 4A	Temperature anoxic tank 10	Turbidity NTU tank 10
10/12/2022 19:32	18.83658	6.281468	3.508863	0.3201969	9061.239	4602.982	0.3201969	17.49188	0.4921
10/12/2022 19:32	18.82946	6.282905	3.504389	0.3202094	8891.122	4851.316	0.3202094	17.48877	0.4939
10/12/2022 19:12	18.82414	6.282461	3.474979	0.3199906	9029.606	4054.51	0.3199906	17.48566	0.481
10/12/2022 19:02	18.81705	6.281369	3.395785	0.3201989	9054.339	3357.523	0.3201989	17.48256	0.4847
10/12/2022 18:52	18.80961	6.281609	3.213308	0.3202433	9055.888	2881.192	0.3202433	17.47945	0.4921

The **Sewer Mining unit** in the Athens Municipal Plant Nursery (NextGen Athens pilot)

25 m³/day at the point of demand
Nutrient and energy recovery solutions

- From disconnected information silo to an online real-world demonstrator
- Descriptive and visual information for easy understanding of the technologies and operations (increase knowledge transfer at various levels)
- Real-world data and performance plots provide insights and evidence for benefits
- EYDAP (Athens' water company) quality analysis measurements (evidence to overcome societal acceptance barriers)
- FIWARE "Smart Water" specification and hardware-independent data connection to *Attica DT* can host any similar real-world pilot.

Knowledge transfer

The new **Sewer Mining unit** for climate proofing in East Attica (IMPETUS pilot)

Urban greening and climate proof against droughts
Municipal ecosystem services
Park irrigation – reduction of heat island effects at local level

- Knowledge transfer from AMPN Sewer Mining
- New technologies to reduce the energy footprint
- Attica DT data to support stakeholders and provide increased insights over regional status and indexes
- Synergies between research – private - public administration in a co-creation scheme
- Support feedback loop between local and regional Communities of Practice (CoP)

Controlled Environmental Agriculture (CEA)

Increase resilience & sustainability of Attica's agricultural sector and adjacent natural habitats

- IMPETUS proof of concept demonstrators with Attica DT support
- Optimise water and fertilizer efficiency, reduce energy consumption, retain or enhance quality crop parameters
- Communication tools, new business models and supporting software services to empower local CEA farms (support local CoP and clustering)

Online services

DT integrated Flood assessment

- Assessment of flood events in the region
- HEC-RAS powered modelling backend
- Tapped into the DT regional database
- Spatial visualisation of impacts and flood characteristics (velocity, water level etc.)
- Real-time or scenario-based

Supporting Reforestation and Biodiversity

- Biodiversity monitoring of different landscapes
- Feedback and knowledge exchange from successful restoration efforts
- "Learning from experience" factors to develop optimal reforestation strategies
- Deep Learning driven (CNN)

Data accumulation and transformation

- Region-wide climatic indexes based on ERA5 Copernicus and local datasets (hard and soft-sensors).



Past: Identify trends, patterns, behaviours and spot changes

Present: Identify climate vulnerable hotspots

Future: Make projections and explore mitigation and adaptation pathways

Integrative regional data and knowledge hub to boost green business models, enable knowledge sharing and CoPs, and reach further into local and regional social web.

- Decision support background** for the identification, prioritisation and characterisation of enabling/driving conditions for technology implementation.

Conclusions

- Attica DT, and relevant regional DTs, can help future-proof our societies through evidence-based co-design of mitigation and adaptation pathways that utilise viable innovative solutions and prioritizing the climate-vulnerable hotspots at regional and local level.
- Regional DTs enable far-reaching knowledge exchange, especially towards policy makers, and can boost the uptake of novel technologies that emerge from European, national or private R&D – creating a more robust green business environment that lives past the end of initiatives.
- Citizen's engagement can eliminate societal barriers, shift policy and lead to faster paces of adoption

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