Article

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Desirable Small-Scale Solar Power Production in a Global Context: Local Tradition-Inspired Solutions to Global Issues

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Abstract: The primary focus is on the large-scale cultural, solar, and environmental contexts that impact small traditional agricultural plots, following the technical input data of agrivoltaic solar power or fish-friendly micro hydropower, considering the cultural landscape. The case study on an existing polder addresses several environmental issues, risk management concerns, energy requirements, and aspects of renewable energy transition, including potential solutions and their impact. Cultural landscape, agricultural plot management, and ecology focusing on traditionally inspired design in rural wetland areas in Romania, Technical vs. Humanistic as a solving path through some inspiring "Dyads"[1] is emphasised in the proposed paper. The Dyads are related to Bennett's systematic approach to ensure the Knowledge necessary to achieve Understanding without experiencing. With a double spiral, the defined methodology applies solar photovoltaic technology to a water-related built environment without reducing or harming the relevant water management related to Nature. The same method applies to solar photovoltaic technology and can be replicated in any built environment with distinct Knowledge-related measures adjusted to updated risks. The replicability of the technique is demonstrated in the article only in the same water-related environment replicable in the traditional Romanian area, achieving the Cultural landscape heritage. Some of the measures are just listed and not detailed on a technical level that can be developed on a particular case study design. The Solar Regeneration monad is a holistic visual framework applied to any built environment for a solar Regenerative Culture.

Keywords: holistic visual framework; energy – nature – built; Solar Regeneration; agrivoltaics; traditional plot landscape; river landscape

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Introduction

The research gap concerns whether the NBS [Nature Based Solutions] [2] traditional design inspired could be replicated in another area. The study considers three pillars: Energy - Nature - Built,

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[1] John G. Bennett, *Elementary systematics: A Tool for Understanding Wholes* (Bennett Books, the Estate of J.G. Bennett, United States of America, 1993), 27.

[2] Carla S. S. Ferreira, Milica Kašanin-Grubin, Marijana Kapović Solomun, Svetlana Sushkova, Tatiana Minkina, Wenwu Zhao and Zahra Kalantari, *Wetlands as nature-based solutions for water management in different environments* (Current Opinion in Environmental Science & Health: Volume 33, June 2023, 100476), 6. "Wetlands have emerged as NBS in various water resources management practices, including regulating the hydrological cycle and

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Energy as Solar Photovoltaics, Nature as Blue & Green, and Built as the cultural Heritage of Traditional landscape. Huderwasser outlined Tradition relevance as a well-known quote: "If we do not honor our past, we lose our future. If we destroy our roots, we cannot grow," and maybe the "The Big Way" [3] painting inspired the Holistic Visual Framework[4].

Any cultural landscape presents a visual, auditory, and olfactory mosaic of material, defined phenomenologically through experiences and events that generate and reveal its history. The rural regions to be analysed are located in two distinct areas of Romania: Zerindu polder, Arad County, Romania [Z-AR], as agricultural plots, and a family plot from Săcuţa locality, Boroaia, Suceava County, Romania [S-SV], one author's family heritage photos & stories as the research base.

The final sections of the paper delve into the technical specifics of solar energy production and storage in agricultural settings. The research will provide a detailed analysis of various agrivoltaic configurations. The final sections of the paper delve into the technical specifics of solar energy production and storage in agricultural settings. The research provides a detailed analysis of various agrivoltaic configurations, their efficiency, and their integration with traditional farming practices. They also explore the potential of green hydrogen production and fish-friendly micro hydropower as complementary energy storage solutions.

The paper's conclusion will synthesize the key findings, revisiting the core dyad relationships and presenting a comprehensive SWOT analysis of the technical strengths of their hybrid approaches, such as the successful integration of agrivoltaic systems and modernized temporary dam systems. Also, is highlighted the research unresolved issues, as the technical issues that require more studies, PV technology technical design based on specific, local meteorological data.

On the humanistic side, is highlighted the preservation of cultural landscapes and traditional farming knowledge. The paper presents a comprehensive study on integrating indigenous and conventional agricultural practices with modern renewable energy systems. The study examines how cultural heritage and local Knowledge can influence sustainable energy solutions, focusing on agrivoltaics and restoring the existing polder systems with nature-based solutions. The humanist side and just conceptual technical side are the relevant issues that are assumed in the research focus area.

Holistic Framework - Methodology

The paper begins by establishing the study's theoretical foundation, drawing on Bennett's Systematics and the concept of the Solar Regeneration Monad[4]. The research introduces three key dyads to guide their analysis: Technology vs. Tradition, Technical vs. Humanist, and Active vs. Passive. These dyads are presented not as contradictory forces but as complementary elements that must be understood and balanced for effective and sustainable development. The methodology section outlines the research approach to analyzing these dyads across multiple scales, from individual agricultural plots to global contexts. They emphasize the importance of integrating traditional Knowledge and modern technical Understanding, using a spiral process to move from "Knowledge" to "Understanding" in each domain.

The chapter on the NATURE dyad explores the relationship between traditional and technological approaches in environmental management. The research focuses on biodiversity

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improving water quality. However, natural wetlands worldwide continue to be threatened by anthropogenic and climate drivers" https://www.sciencedirect.com/science/article/pii/S2468584423000363 (visited: april 2025).

[3] Caro Weisauer, *100 Questions about Hundertwasser* (100 X Hundertwasser. Artist-Visionary-Nonconformist, METROVERLAG: 2016, ISBN 978-3-99300-261-9), 31, 35. "Hundertwasser was convinced that the creation of the earth took place in spiral form". https://www.kunsthauswien.com/en/education/100-x-hundertwasser/ (visited: april 2025).

[4] Nina Cristina Dițoiu, Ph. D. Thesis – Summary "The regenerative culture of the built environment: Multicriteria decisions in the double-way spiral", 2023. https://doctorat.utcluj.ro/theses/view/OZxZ2SPxgn5edlY60K2Gi3FKCdAH5uP4XDqNfXmH.pdf (visited: april 2025).

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metrics, carbon sequestration potential, and integrating conventional and indigenous water management systems with modern agricultural technologies. A particular focus is placed on the role of wetlands and their preservation in the face of Anthropocene-driven changes.

The BUILT dyad examines the intersection of humanistic and technical approaches in agricultural infrastructure and energy production. The research examines the assessment of cultural heritage, traditional building practices, and the adaptation of rural structures to integrate renewable Energy. Case studies of traditional rural plots in Boroaia and Anthropocene agricultural plots in the Zerind Polder highlight how this balance can be achieved.

The ENERGY dyad explores the relationship between passive and active energy systems, analyzing carbon footprint, water footprint, and the potential for renewable energy generation.

The research presents detailed assessments of agrivoltaic systems, translucent photovoltaic coverings for irrigation canals, and the integration of fish-friendly micro-hydropower. Dyad proposed **it** related to a Monad after Bennett Systematics was "Knowledge vs. Understanding"[5].Dyads proposed related to a "Solar Regeneration" Monad are as follows:

- "Technical *vs*. Humanist" *as* **BUILT Criteria**
- "Technology *vs*. Tradition" *as* **NATURE Criteria**
- "Active *vs*. Passive" *as* **ENERGY Criteria**

The theme relevant in the DYAD-related context is *"vs./versus"* or "Together despite opposites"'. "Knowledge" without "Understanding" is somewhat equivalent to "Technical" / "Technology" / "Active" without their opposites: "Humanist" /" Tradition"/"Passive", all opposites together without prioritization. The Dyad needs the impulse to move in a Triad understanding process. The spiral is proposed as a process to achieve a monad; the impulse required, in addition to the Dyad opposing terms, is the grow-degrow impulse. Translating the "Knowledge" criteria into "Understanding" requires a process. Bennett's systematics offers a set of regulations applicable to the abstract, an academic way of reaching "Understanding" - through the antithesis-thesis (Dyad) to the Hegelian dialectic (thesis, antithesis, synthesis), similar to the impulses of Bennett's Triad. The Hegelian dialectic offers a way of developing in a one-way spiral. But Bennett's Triads provide a way of gaining and re-gaining through a double-way spiral covering the "Knowledge" necessary for achieving "Understanding" and making a multicriteria decision essential in any holistic solution. The spiral way sketches note the equal weight of the knowledge metaphors in the creation of the rosette:

B—BUILT+ E—ENERGY+ N—NATURE on the scales from small to large,
O—Object, L—Locality, T—Territory, G—Global, applied for projects on any starting points.

Methodology - Knowledge *vs.* Understanding Solar Regeneration-related Dyads

Dyads - Knowledge *vs* Understanding as Technology *vs.* Tradition / Technical *vs.* Humanist / Active *vs.* Passive.

"Knowledge *vs.* Understanding" is the Dyad according to the views of Bennett, who detailed systematics to make the transition from "Knowledge" to "Understanding", which usually requires experimentation.

So the *"vs./versus"* inside the main Dyads means "opposite but together" and represents the research Gaps of the "Solar Regeneration" Monad we try to whole.

We can develop a "3—Active *vs.* Passive" Dyad related to the Energy transition from Energy Criteria or the same "2—Technology *vs.* Tradition" Dyad in the Ecological transition of Nature Criteria; a "1—Technical vs. Humanist" Dyad related to an Urban metabolism for the Built Criteria.

KNOWLEDGE is defined through TECHNICAL criteria for NATURE - BUILT - ENERGY[6] and is somewhat partially related to ENVIRONMENT-SOCIAL-GOVERNANCE in many ways.

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[5] John G. Bennett, *Elementary systematics: A Tool for Understanding Wholes* (Bennett Books, the Estate of J.G. Bennett, United States of America, 1993), 9.

[6] Nina Cristina Dițoiu, Ph. D. Thesis – Summary "The regenerative culture of the built environment: Multicriteria decisions in the double-way spiral", 2023.

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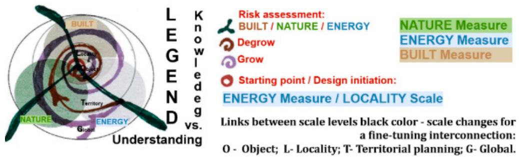

Figure 1. Visual Holistic Framework - Methodology Diagram Dyads related + grow -degrow process[7].

Figure 1 Visual Holistic Framework - Methodology[7] Dyads related + growth-degrow process required as follows: Regenerative Monad: Dyad, according to Bennett[8], "—Knowledge" learned or transmitted requires a grow - degrow process for achieving "—Understanding" that typically involves experimentation. After criteria related to Knowledge in Table 1 are determined three dyads:

1—Nowadays, Regenerative, the New Dyad "1—Tradition" needs to be perfected after many "1—Technology" implementations on different scales in a growth-degrow fine-tuning process.

2—Nowadays, Regenerative, the New Dyad "2—Humanist" needs more "2—Technical" accomplishments, which are often repeated in the same fine-tuning grow-degrow process.

3—Nowadays, Regenerative, the New Dyad "3—Passive" achievement is flawless through an optimal "3—Active" after a growth-degrow fine-tuning process.

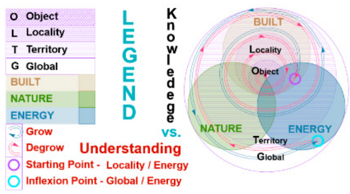

Figure 2. Visual Holistic Framework [7]- Methodology Diagram Dyad Knowledge **vs.** Understanding, "the Knowledge **vs** Understanding diagram": Legend Scales O Object; L Locality; T Territory; G Global/ N Nature + B Built + E Energy; Grow – Degrow process from a Starting point, as Locality scale – polder.

Table 1. Criteria related to Knowledge like/ 1-Technology, 2-Technical, 3–Active to achieve 1-Tradition, 2-Humanist, 3-Passive/as Understanding.

Acronym	measure↓	LEGEND - MEASURE/SCALE	
N - O	Nature - Object	NATURE **Technology**	OBJECT plot scale
N - L	Nature - Locality	NATURE **Technology**	LOCALITY dam/polder scale
N - T	Nature - Territory	NATURE **Technology**	TERRITORY hydrologic basin scale
N - G (*)	Nature - Global (*)	NATURE **Tradition**	GLOBAL scale (*)
B - O	Built - Object	BUILT **Technical**	OBJECT plot scale
B - L	Built - Locality	BUILT **Technical**	LOCALITY dam/polder scale
B - T	Built - Terilor	BUILT **Technical**	TERRITORY hydrologic basin scale
B - G (*)	Built - Global (*)	BUILT **Humanist**	GLOBAL scale (*)
E - O	Energy - Object	ENERGY **Active**	OBJECT plot scale
E - L	Energy - Locality	ENERGY **Active**	LOCALITY dam/polder scale
E - T	Energy - Territory	ENERGY **Active**	TERRITORY hydrologic basin scale
E – G (*)	Energy – Global (*)	ENERGY **Passive**	GLOBAL scale (*)

(*) The Global-scale is the "correct assessment," including sine qua non-design principles and the Humanist related to Understanding.

[7] ibidem, Dițoiu, N.C.'s concept, Sketch & cad drawing.

[8] John G. Bennett, *Elementary systematics: A Tool for Understanding Wholes* (Bennett Books, the Estate of J.G. Bennett, United States of America, 1993), 8-17.

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Table 2. [9] [DNSH] Do No Significant Harm principle.

1	Climate change mitigation	renewable energy production	**Substantial contribution**
2	Climate change adaptation	flood protection, [NBS] [2]	**Substantial contribution**
3	DNSH The sustainable use and protection of water and marine resources	Polder - wetland	**Substantial contribution**
4	DNSH The transition to a circular economy	recycled materials, preserved built works	**Substantial contribution**
5	DNSH Pollution prevention and control	attention needed - materials	**DNSH**
6	DNSH The protection and restoration of Biodiversity and ecosystems	Wildlife corridors with biocapacity/biodiversity - wetland impact	**Substantial contribution**

NATURE[10] — Regenerative Dyad "Tradition vs. Technology"

The Dyad examines the relationship between traditional and technological approaches in natural contexts, focusing on Biodiversity, agriculture, and environmental management. The research analyses how traditional agricultural practices and modern technological solutions can be integrated to enhance Biodiversity and ecological sustainability. The analysis is conducted across different scales, from individual plots to entire ecosystems. Specific attention is given to the role of wetlands, traditional water management systems, and their integration with modern agricultural technologies.

The chapter includes a detailed assessment of biodiversity metrics, carbon sequestration potential, and the impact of different land management approaches on natural systems.

Table 3. NATURE 1—Nowadays, the New "1—Tradition" needs to be perfected after many "1—Technology" implementations on different scales in a grow-degrow process.

Scale Global	**correct assessment**
Green	Increased Biodiversity of local species measures (after invasive species issues)
Agriculture	Following the Anthropocene-specific era of industrial agriculture, locally adapted cultures for regenerative. Pesticide-free European agriculture
Blue	Water management - longitudinal connectivity & transversal connectivity related to wild corridors (after Anthropocene excessive Hydropower measures, excessive micro hydro number)
Biodiversity	Wetland areas and longitudinal watercourse connectivity (following the Antropocene's decreased Biodiversity)
Soil	Soil health measures are needed after the Anthropocene - specific soil degradation.
Risks related	Water Scarcity / Risks relevant to energy production are to be evaluated
Scale Object	**plot**
Green	Increasing biocapacity/ biodiversity
Agriculture	Pesticide-free crop rotation, Increasing Biodiversity
Blue	Irrigation canals needed/ ponds needed
Biodiversity	Increasing biodiversity measures, connectivity related to wild corridors
Soil	Pesticide-free crop rotation
Risks related	Water footprint/ Energy production to be evaluated

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[9] https://ec.europa.eu/sustainable-finance-taxonomy/home (visited: april 2025).

[10] https://ec.europa.eu/sustainable-finance-taxonomy/home Related to 4 taxonomy criteria: DNSH The protection and restoration of biodiversity and ecosystems; DNSH Climate change mitigation; DNSH Climate change adaptation; DNSH The sustainable use and protection of water and marine resources (visited: april 2025).

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Scale Locality	dam/polder
Green	Increasing biocapacity/ biodiversity
Agriculture	Pesticide-free crop rotation, Increasing Biodiversity
Blue	Irrigation canals needed/ ponds&dams needed, longitudinal connectivity & transversal connectivity related to wild corridors
Biodiversity	Biodiversity improvement measures, such as meander renaturation, connectivity related to wild corridors
Soil	Pesticide-free crop rotation in an agricultural community
Risks related	Water footprint/ Energy production to be evaluated
Scale Territory	Hydrological Basin
Green	Increasing biocapacity/ biodiversity
Agriculture	Pesticide-free crop rotation, Increasing Biodiversity
Blue	Wetland areas, dams needed, longitudinal connectivity & transversal connectivity related to wild corridors
Biodiversity	Increasing Biodiversity measures for local species, connectivity related to wild corridors
Soil	Soil health improvement measures
Risks related	Water Scarcity /Biodiversity issues/ Energy production to be evaluated

BUILT[11] — Regenerative Dyad "Humanist vs. Technical"

This Dyad analyses the intersection of humanistic and technical approaches in built environments. The research examines how cultural heritage, traditional building practices, and modern technical solutions can be integrated into agricultural and Energy infrastructure. The analysis covers heritage value assessment, cultural landscape preservation, and social aspects of development. Particular attention is paid to adapting traditional rural structures for modern energy production while maintaining their cultural significance.

The chapter thoroughly examines how indigene/traditional property boundaries and land use patterns can be preserved while incorporating modern renewable energy systems.

Table 4. BUILT 2—Nowadays, the New "2—Humanist" needs more "2—Technical" accomplishments, which are often repeated in the same grow - degrow process.

Scale Global	correct assessment
Recyclable	The existing built environment that supports PV systems
Heritage Value	Revitalizing the traditional household after vernacular heritage-specific degradation in the Anthropocene
Cultural Landscape	Revitalizing the cultural landscape after a possible Anthropocene-specific degradation
Social	Traditional agricultural plots for energy community / agrarian communities' circular metabolism community.[12]
Degrowth	Revitalizing an intangible heritage through measures specific to traditional culture encompasses daily life routines that follow the circadian cycle and agricultural activities that follow the lunar cycle
Risks related	Risks relevant to energy production are to be evaluated.
Scale Object	plot
Recyclable	Built environment rehabilitation - photovoltaic support

[11] https://ec.europa.eu/sustainable-finance-taxonomy/home Related to 3 taxonomy criteria: DNSH Climate change mitigation; DNSH Climate change adaptation; DNSH The transition to a circular economy (visited: april 2025).

[12] Aristide Athanassiadis, https://www.circularmetabolism.com/ (visited: april 2025).

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Heritage Value	Cultural landscape preserved on traditional plots, particular heritage elements, as fences or others
Cultural Landscape	Traditional landscape design
Social	Social Impact of Agrarian/ Energy Communities
Degrowth	Agrarian/Energy communities according to a traditional design
Risks related	Risk of aggressive intervention in the cultural landscape
Scale Locality	**dam/polder**
Recyclable	Circular metabolism on a large scale as a metropolitan/ basin scale[12]
Heritage Value	Industrial dams – evaluated as industrial/technical heritage value
Cultural Landscape	Cultural heritage preservation
Social	Human-centred measures large-scale, infrastructure interventions with social impact evaluated
Degrowth	Degrowth and interconnectivity in large-scale infrastructure interventions
Risks related	Energy production / Biodiversity to be evaluated
Scale Territory	**hydrological basin**
Recyclable	Heritage preservation as a circular economy measure
Heritage Value	Heritage studies, thematic heritage visit route basinal scale
Cultural Landscape	Cultural landscape studies
Social	Circular metabolism[12] / Energy / Agrarian communities
Degrowth	Heritage preservation as a degrow measure
Risks related	Biodiversity issues / Energy production to be evaluated

ENERGY[13] [14]—Regenerative Dyad "Passive vs. Active"

The Dyad explores the relationship between passive and active energy systems in agricultural contexts. The research analyses different energy generation and consumption approaches, examining carbon footprint, water footprint, renewable energy potential, and energy consumption patterns across various scales. The study includes a detailed assessment of how traditional passive energy systems can be integrated with active solar power generation. The analysis covers specific metrics for energy efficiency and environmental impact, including carbon sequestration potential and water usage efficiency in different agricultural systems.

Table 5. ENERGY 3—Nowadays, the New "3—Passive" achievement is achieved through an optimal "3—Active" process after a growth-degrowth process.

Scale Global	**correct assessment**
Carbon footprint	Carbon sequestration through nature-based solutions measures
Water footprint	Related to hydrogen production and hydropower production
Renewable Energy	Agrivoltaics, translucent solar panels on irrigation canals, micro-hydro fish-friendly
Energy Consumption	Hydrogen production
Risks related	Water / Energy / Built / Biodiversity risks related
Scale Object	**plot**
Carbon footprint	Plot Carbon footprint / Carbon storage to be assessed
Water footprint	Irrigation needed
Renewable Energy	PV production to be assessed

[13] https://ec.europa.eu/sustainable-finance-taxonomy/home Related essential to one taxonomy criteria: DNSH Climate change mitigation (visited: april 2025).

[14] Peter Droege, ed., *URBAN ENERGY TRANSITION Renewable Strategies for Cities and Regions* (Elsevier, 2018), 31-49, 85-113.

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Energy Consumption	Irrigation pump consumption to be evaluated
Risks related	Water / Biodiversity issues /Energy / Built risks related
Scale Locality	**dam/polder**
Carbon footprint	Carbon footprint / Carbon storage to be assessed
Water footprint	Hydrogen and hydropower production to be evaluated Irrigation needed, Biodiversity wetland needs
Renewable Energy	Hydrogen production/PV production to be assessed
Energy Consumption	Irrigation pumps consumption/Consumption in Hydrogen production to be evaluated
Risks related	Water / Biodiversity issues /Energy / Built risks related
Scale Territory	**hydrological basin**
Carbon footprint	Carbon storage to be assessed
Water footprint	Hydrogen and hydropower production and other consumers to be evaluated
Renewable Energy	Production to be assessed/ potential production
Energy Consumption	Consumers/potential consumers
Risks related	Water / Biodiversity issues /Energy / Built risks related.

New BUILT [S-SV] vs. [Z-AR] Regenerative Dyad "Humanist vs. Technical"

The conventional wetland in Arad County was designed as a non-permanent water accumulation area. [Z-AR][15] vs. [S-SV] Săcuța village, Boroaia, Suceava County, an area at the confluence of two watercourses with fluctuating flows, naturally creates a temporary wetland. The connection between the two sites seems coincidental, but it was about an exodus in the Suceava area of over 150 families from a village in Banat due to a plague epidemic in the 15th century. We can only assume that some of them or their know-how was transmitted by some C. family members, according to the words of some old Boroaia teacher and details that are not very specific in the village monograph.

The area of the village of Boroaia [S-SV] has relatively unproductive agricultural lands. For this reason, and due to the morphological environment, some risk management works related to the watercourse are considered risk management according to current norms. However, the hydrotechnical works in [S-SV] Boroaia, Suceava County, were determined by the eloquently named watercourse, Seaca/tr Drought/Dry, which presents torrent-like flow fluctuations. Such techniques are not specific to the Moldova River basin's ethnological or morphological geographical area. They seem to have emerged by acquiring technical Knowledge from migrants from a traditional wetland area, such as Arad County. The migrants implemented secular agricultural practices, including water management systems, which were traditional in the distinct support areas with a Neolithic history. However, they could find this locally, having transferred know-how from the Arad area, specifically from or near the Zerind polder area. So, the other location to be analyzed, Zerind Polder [Z-AR][15], is a temporary dam area enclosed by dikes, demonstrating human adaptation to wetland conditions through traditional Anthropocene engineering. However, this can also be historically documented in the Banat area (Figure 4) as the implementation of landscape-specific techniques (ditches as crop boundaries, plots linked to dwellings/households delimited by arranged ditches). A network of rivers and streams characterises both sites, and the creation and management of water channels have shaped a cultural landscape with a specific set of traditional activities over time.

Traditional property boundaries mark the landscape, and agricultural plots reflect historical land use patterns through the design and management of indigenous ditches versus modern

[15] *Aqua Prociv Proiect*, Company, Cluj-Napoca, Romania, "Renaturation of Zerind & Tămaşda polders, Arad and Bihor counties" (Romania Team Project: Concept Sketch &cad drawing landcape design - Arch. Nina Cristina Dițoiu; Cad Drawings & Hidrotechnical Design - Eng. Dragoş Gros, Team Coordinator Eng. Dan Săcui).

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Anthropocene adaptations of flood risk management, such as the construction of dikes and polders. The Boroaia traditional rural plots and the Zerind Polder case studies offer a rich contrast, showcasing how traditional Knowledge can design modern sustainable practices.

The Boroaia (Figure 3) case examines historical land use patterns, water management systems, and indigene cultural practices conserved in a vernacular village, Săcuța. At the same time, the Zerind Polder [Z-AR][15] represents a more contemporary approach to agricultural production within the Anthropocene era.

Traditional rural plots [S-SV] vs. [Z-AR] Antropocen agricultural plots

This Dyad presents detailed case studies of two contrasting agricultural settings: traditional rural plots in Boroaia, Suceava County [S-SV] *vs.* [Z-AR] Anthropocene agricultural plots of Zerindu Polder. The research examines historical land use patterns, traditional water management systems, and cultural practices in Boroaia, dating back to the older centuries. The Zerind Polder [Z-AR] analyses modern agricultural practices, water management systems, and the potential for renewable energy integration. The comparison highlights how traditional Knowledge can inform modern sustainable practices while addressing contemporary agrarian production and energy generation challenges.

Romanian history significantly shaped the region's rural settlement patterns and agricultural traditions. The uprising led to the widespread reorganization of rural communities, establishing distinctive property boundaries and traditional farming plots that remain visible in today's cultural landscape. In its aftermath, many communities adopted specific agricultural practices and land management approaches, particularly in areas like Boroaia, where traditional plot layouts and water management systems reflect this historical influence. The uprising's legacy is evident in the spatial organization of rural settlements, the preservation of communal farming traditions, and the cultural emphasis on maintaining traditional agricultural Knowledge alongside technological advancement.

This historical event created enduring patterns in how local communities approach land use, water management, and the balance between traditional practices and modern development, making it particularly relevant to contemporary discussions about sustainable agricultural development and cultural preservation in Romanian rural areas. The ancestral agricultural and water management practices, developed over years in Romania's rural wetlands, represent a sophisticated environmental adaptation and sustainable resource management systems.

These practices evolved through generations of careful observation and accumulated wisdom. The agricultural system features carefully planned field patterns following natural topography, utilizing terraced slopes and drainage channels. Farmers traditionally divide the land into small, irregular plots that work with rather than against the natural water flow patterns. This approach helps prevent soil erosion while maximizing water retention in drier periods. Water management practices are particularly noteworthy in wetland regions, where communities developed intricate networks of channels, retention ponds, and natural filters. These systems demonstrate remarkable efficiency in managing seasonal flooding, directing excess water away from crops while retaining enough moisture for dry periods. Traditional Knowledge includes precise water release and retention timing based on seasonal patterns and crop needs.

The practices incorporate sophisticated crop rotation patterns that maintain soil fertility naturally, with specific combinations of plants chosen for their mutual benefits and adaptation to local conditions. Traditional field boundaries often feature specific vegetation for multiple purposes: marking property lines, providing windbreaks, and supporting local wildlife. These systems represent more than mere practical solutions - they form an integral part of the cultural heritage, with specific traditions, customs, and ceremonies associated with different agricultural activities throughout the year.

The Knowledge is traditionally passed down through generations, with each community maintaining its unique variations adapted to its specific microclimate and terrain. After historical maps, both sites are archeological heritage [S-SV] Secuta Cimec archaeological map Tumular

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necropolis Daco-Roman period (3rd - 4th century) RAN 147081.01 LMI code SV-I-s-B-05398[16] *vs.* [Z-AR] Zerindu/Tămaşda Cimec archaeological map, the Josephine Map, 1782-1785[17].

BUILT [S-SV] Study case Traditional rural plots – Boroaia, Suceava county, Romania

Traditional rural plot - Historical assessment[18,19].

The origin of the Boroaia village name is based on the "hypothesis of transfer from Transylvania". This hypothesis is also mentioned in the monograph of the locality, which considers it reasonably certain[20]. The Banat area is remembered for the 150 families that left the village of Macea, Arad County, for Moldova, near Suceava[21]. Boroaia and Săcuţa are known to have been established around 1772-1774, but the documentation is unavailable.

Historical, village monography reveals some dates: "Boroaia is also a prehistoric locality (...) and on the terrace of the Tîrziu stream, (...) Neolithic (Cucuteni phase A)"[22], archaeological protected – near Boroaia village Tumular necropolis Daco-Roman period (3rd - 4th century)[23].

"Hydrological data". Săcuţa village[24] / Secuţa in Moldavia (1892-1898) map is related to the Romanian Seaca river (name translation as Dry, Drain), a temporary flowing river. Decreasing the

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[16] ran.cimec.ro cimec map Tumular necropolis Daco-Roman period (3rd - 4th century) RAN 147081.01 LMI code (List of Historical Monuments) List of Historical Monuments from 2010, SV-I-s-B-05398 (visited: april 2025).

[17] ran.cimec.ro cimec map

[18] Gheorghe Scripcaru, *BOROAIA O reintoarcere in spirit* (Monografie reeditată comuna Boroaia ISBN 973-98476-5-X, 2013), 87-88, 90. *[tr.n.]"Names of some families (...) C." Boroaia "hypothesis of transfer from Transylvania", "Transylvanian words among the village inhabitants (dar-ar, lual-ar, mancai-ar, basna, ciubar, flacau (...) pisti, tongue, house, amu, etc.)" (...) "from a certain Bora and Boroaia's wife, with whom the peasants emigrated from Transylvania".*

[19] Ion Ghinoiu, (coordonator general), *Habitatul. Răspunsuri la chestionarele Atlasului Etnografic Român* (Volumul IV Moldova, ISBN 978-973-8920-23-1 Ed. Etnologică, București, 2017).

[20] Gheorghe Scripcaru, *BOROAIA O reintoarcere in spirit* (Monografie reeditată comuna Boroaia ISBN 973-98476-5-X, 2013), 39. *[tr.n.]"Undoubtedly, the name of the village comes from a man named Bora from Transylvania, with which the population took refuge in this area on the estates of the Rasca and Neamt monasteries after Horia's uprising, and Bora, which derives from Bor, imposes itself as a purely Romanian word".*

[21] Ion Ghinoiu, (coordonator general), *Habitatul. Răspunsuri la chestionarele Atlasului Etnografic Român* (Volumul II Banat, Crișana, Maramureș, ISBN 978-973-8920-21-7 Ed. Etnologică, București, 2010), 114. *[tr.n.]"In 1480, it is said that Macea had 4800 souls, who mostly disappeared after a plague, about 50 families remained, 150 families left Moldova, near Suceava: Ar 8".*

[22] Gheorghe Scripcaru, *BOROAIA O reintoarcere in spirit* (Monografie reeditată comuna Boroaia ISBN 973-98476-5-X, 2013), 25. *[tr.n.] "in Drăguşeni, the archaeological excavations of V. Ciurea discovered (...) concludes that Boroaia is also a prehistoric locality (...) and on the terrace of the Tîrziu stream, N. Zaharia also found fragments of bones, anthropic and zoomorphic figurines and a flat stone axe belonging to the developed Neolithic (Cucuteni phase A)".*

[23] ran.cimec.ro cimec map Tumular necropolis Daco-Roman period (3rd - 4th century) RAN 147081.01 LMI code (List of Historical Monuments) List of Historical Monuments from 2010, SV-I-s-B-05398 (visited: april 2025).

[24] Secuta, Moldavia (1892-1898) map https://maps.arcanum.com/en/map/romania-1892/?layers=22&bbox=2968946.7689266833%2C6061625.993676056%2C2975910.6244568615%2C6064161.797620838. (visited: april 2025). *[tr.n.] "The groundwater is at a depth of 6-18 m, and in some places, it reaches 30 m. (...) The Moldova River has an unstable riverbed and often causes floods. Also, on the commune's territory, the Risca stream is confluent with the Moldova River, which increases the risk of these floods. The hydrographic network is formed by the Moişa and Săcuţa streams that flow into Saca, the latter into the Risca River and Risca into the Moldova River. When it rains, the flow of these streams is very high, and when there is drought, the streams dry up completely (hence the name) due to the bed formed by very permeable rocks".*

scale, a family plot area, "the names of some families (...) C. family name,"[25,26] appears as one of them, and teacher Nicolae Cercel[27] remembered this family origin is from the Banat area, Transylvania[28]. The plot for the first family member, named C., dated 1899[29], bears the same name as that of other villages in the same county, such as SV3-Brosteni, a village with inhabitants of Transylvanian origin. The same origin of the relocated inhabitants was noticed for Fundu Moldovei village, Mălini, where the ditches appear as plot limits a particular measure for a wetland landscape, Păltinoasa, Stuplicani, Vatra Moldoviței and Brodina de Sus[30]. Banat is a known wetland that is scarce in warm periods. The family origin seems to import the know-how for managing a related confluence of the rivers with wetlands areas in rainy times of the year and scarcity in warm periods. Diches on property limits, as well as landscape management related to different plot areas, ponds, springs and fountains, vegetation near flowing water, and related temporary wetlands, are some specificities related to an extended area of one family origin. The period related to the Anthropocene was well focused on agricultural production, and these land works were significant in one year, with specific traditions and cultural immaterial heritage. In the 2000s, the village decreased its activities due to relative abandonment. The reduced maintenance of land works affected the landscape and caused landslides near the watercourse. However, it also expanded vegetation to a degree of wildness that transformed wetlands into protected areas, a desirable post-Anthropocene regenerative design[31]. This evolution is also documented on GIS maps.

Figures 3-4 are on the cadastral support image ancpi/geoportal map [S-SV], with areas related to the extended family marked with numbers. Ponds are also marked to define a blue-green corridor visible on the anterior map plans with decreased/increased green spaces related to the year affiliated - GIs maps from 2005 till 2024. Sentinele 2 land cover[32,33] year 2017 vs. 2024 compared, land cover evolution for plot 3 No marked in the context of changed land use. If the two Sentinel 2 maps reveal a decreased green area for the entire Săcuța locality, the blue-green corridor increased can be noticed.

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[25] Ion Ghinoiu, (coordonator general), *Habitatul. Răspunsuri la chestionarele Atlasului Etnografic Român* (Volumul IV Moldova, ISBN 978-973-8920-23-1 Ed. Etnologică, București, 2017).

[26] https://dragusanul.ro/povestea-asezarilor-sucevene-boroaia/ (visited: april 2025). *[tr.n.]"**Although the uric of August 4, 1400, by which Alexander the Good (...)** «**A village, of Berea**» **appeared, not only through name to Boroaia (...)** 1796: (...) When it is concluded that the Saca Valley (Sacuta location) (...) located between Bogdănești and Boroaia (at that time - the proof that the current hearth of Boroaia is later), (...) commands them to move to these estates in Saca Valley".*

[27] https://www.comunaboroaia.ro/muzeul-neculai-cercel/ (visited: april 2025).

[28] http://boroaia.uv.ro/5.htm (visited: april 2025).

[tr.n.]"inhabitants of Boroaia village came from Transylvania between 1742 and 1774, which constitute two certain historical references; One (1742) that does not include the Boroaia among the estates of the monasteries Râzca, Neamt and Secu, another that includes (1774) as the estates of these three monasteries, when their captain, Bora, dying, remained the woman of Boroaia (Bora's feminine)".

[29] https://dragusanul.ro/povestea-asezarilor-sucevene-boroaia/ (visited: april 2025).

[tr.n.] "1899: It is published towards the general knowledge that, on November 18, 1899, 11 hours, will be held, in the premises of the City Hall of the respective communes on which each of the goods noted below, oral public auction for leasing the lands, of hay and of the mountain hollows for the pasture, by their land, Boroaia: (...) C. Family name (7 ha, 8000 sqm)".

[30] Ion Ghinoiu, (coordonator general), *Habitatul. Răspunsuri la chestionarele Atlasului Etnografic Român* (Volumul IV Moldova, ISBN 978-973-8920-23-1 Ed. Etnologică, București, 2017), 39, 140, 143-144, 451-454.

[31] Martin Brown, *FutuRestorative: Working Towards a New Sustainability* (RIBA Publishing, 2016) https://fairsnape.com/2016/03/23/futurestorative-working-towards-a-new-sustainability/ (visited: april 2025).

[32] https://livingatlas.arcgis.com/landcoverexplorer/ (visited: april 2025).

[33] https://dataspace.copernicus.eu/ (visited: april 2025).

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Figure 3. [S-SV] 2005; 2009; 2012; 2015; 2024 years, edited map source[34].

Figure 4. [S-SV] Area related to C. name family with ponds marked blue colour - families same name & origin 2021's year map dated[34]No. legend: *1. Gheorghe C. - Cad. No. 30490 ; 2. Ion C.- no Cad. No. ; 3. Ilie C. V. – pond & fountain; no Cad. No. ; no Cad. No.; pink color underlined; 4. Ion C.- Cad. No. 34022; 5. Costache C.- pond; Cad. No. 34822; 6. Ion C. - no Cad. No. ; 7. Mihai C.- pond; Cad. No. 30161; 8. Gheorghe C. V. – pond; Cad. No. 33577.*

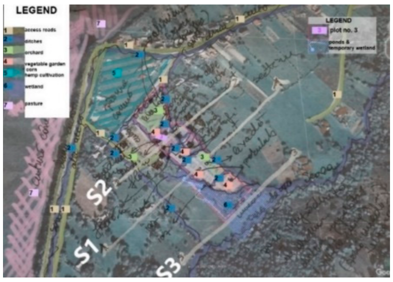

Figure 5. [S-SV] planimetric Ditoiu, N.C.' sketch, edited map source[34].

Figure 6. [S-SV] 6.1 Ditoiu, N.C.' personal dated photos; 6.2 Ditoiu, N.C.' Sections sketch with ponds and ditches, particular measures for a wetland landscape.

Figures 5 [S-SV] Planimetric sketch and Figure 6.2 [S-SV] other sketches of the No. 3 plot, Ilie C.'s plot traditional landscaping – sketched plan, land sections, and Figure 6.1 [S-SV] photos of the pond and watercourse wetland area. Every part of Plot No. 3 was landscaped in a family-oriented, almost urbanistic design environment, featuring a house with a front flower garden, a yard, a vegetable garden, a beehive yard, a cornfield, and a pasture, all delimited by numerous ditches and a natural wetland with a pond area. The pond continues the ponds set till the watercourse, with the natural wetland for most of the year boundaries by the Seaca watercourse.

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[34] https://geoportal.ancpi.ro/imobile.html (visited: april 2025).

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BUILT [Z-AR][35] Study case Anthropocene Agricole plots - Zerind Polder, Arad County, Romania

The TRIAD for small-scale regeneration proposes re-naturalization for NATURE, rehabilitation for BUILT, and solar energy production for ENERGY in the particular Romanian polder. NATURE - As wetlands by restoring the courses of the old meanders and replacing the inner dykes space in the polders as canals with wetland landscape works.

Depending on how the population assimilates the new measures, smaller channels along the property boundaries are proposed to delimit areas with the same agricultural culture. Changing the culture will develop communities within the polders for ecological agriculture without pesticides, replacing them with temporary land flooding. Some agricultural plots will be agrivoltaics areas to achieve a proper particular for some specific cultures and renewable energy production.

[Z-AR]: Sentinele 2 land cover[36], 2024 is very similar to the Sentinele 2 land cover map since 2017, and Copernicus Sentinele 2 for wetland areas[37], where can be still noticed Old meanders needed for renaturation, with impact in Biodiversity, Biocapacity as will be detailed NATURE Regenerative Dyad.

The ENERGY areas (Figure 17) for agriculture are marked by canals on property boundaries, which will provide access to water during dry periods (Irrigation) and minimal protection against crop flooding during rainy periods, which appear as plot boundaries in the traditional wetland area landscape[38].

There are also well-known NBS[2] [Nature Based Solutions] that address various challenges, from food security to natural disaster risks. Among the benefits of wetlands, we can mention the increase in Biodiversity, the expansion of carbon storage, the restoration of water reserves, protection against floods and drought, and the ecological agriculture seen in these polders. Polder's area dates back to the 20th century, and we have already admitted that the traditional family plot landscape with dikes is also part of the cultural heritage of Banat wetlands areas[39].

New NATURE [Z-AR] Regenerative Dyad "Tradition vs. Technology"

Table 6. Biodiversity & Carbon Sequestration[40] .

Carbon Sequestration (Tones of Carbon per year)	Boreal Forest	Temperate Forest	Temperate Grassland	Tropical Forest	Desert and semi-desert	Tundra	Wetland	Tropical Savana	Croplands
Surface (ha)	1	1	1	1	1	1	1	1	1
Vegetation Carbon Sequestration	64	120	7	120	2	6	43	29	2
Soil Carbon Sequestration	344	123	236	123	42	127	643	117	80
Overall Carbon Sequestration	408	243	243	243	44	133	686	146	82

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35 *Aqua Prociv Proiect*, Company, Cluj-Napoca, Romania, "Renaturation of Zerind & Tămaşda polders, Arad and Bihor counties" (Romania Team Project: Architecture Concept Sketch - Arch. Nina Cristina Dițoiu; Cad Drawings & Hidrotechnical Design - Eng. Dragoş Gros, Coordinator Eng. Dan Săcui).

36 https://livingatlas.arcgis.com/landcoverexplorer/ (visited: april 2025).

37 https://dataspace.copernicus.eu/ (visited: april 2025).

38 Ion Ghinoiu, (coordonator general), *Habitatul. Răspunsuri la chestionarele Atlasului Etnografic Român* (Volumul II Banat, Crișana, Maramureș, ISBN 978-973-8920-21-7 Ed. Etnologică, București, 2010), (Volumul III Transilvania, ISBN 978-973-8920-31-6, Ed. Etnologică București, 2011).

39 ibidem.

40 https://www.wkcgroup.com/tools-room/carbon-sequestration-calculator/ (visited: april 2025).

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Table 6, on Biodiversity and Carbon Sequestration, is essential for a technical evaluation of different land covers. We can notice that the Wetlands area per ha unitary surface has the best carbon sequestration/ year and overall vegetation + soil. Suppose the Forest is better at vegetation Sequestration, with a value of 120 tonnes of Carbon per year. In that case, soil sequestration puts the wetlands in the first and best option, with a large difference: overall 686 tonnes per year compared to the overall 243 tonnes for temperate Forests.

Carbon Sequestration is needed to incorporate Biodiversity, as measured by Table 6 Biodiversity metrics, into any budget that assumes carbon Credits in cases where biodiversity credits are not available. The "Biodiversity metrics" instrument is a more accurate comparative G-res tool for dams and polders. It is similar to those available in the United Kingdom, but not with the same level of accuracy. There appears to be a gap in implementing local biodiversity tools and biodiversity credits.

Table 7. Biodiversity metrics[41] *vs.* G-res tool biodiversity metrics[42].

Biodiversity metrics	G-res tool metric
Cropland	Cropland
Grassland	Grassland/Shrubland
Heathland and shrub / Tundra	
Intertidal Hard Structures	Bare area
Intertidal sediment	Permanent snow/Ice
Lakes	Waterbodies
Sparsely vegetated land	
Urban	Settlements
Woodland and Forest	Forest
Coastal Saltmarsh	Drained Peatlands
Rivers	Wetland

Figure 7 is the concept for the polder with the relevant works proposed in a regenerative design – NATURE with Biodiversity works (Tables 6 and 7), ENERGY measures also noted:

1. Watercourse's longitudinal connectivity with minimal interventions like fish-friendly micro hydropower;
2. polder boundary preservation of built dykes - internal polder contour channel;
3. old meander renaturation;
4. The old internal polder dike was abolished and designed as a canal with a wetland area landscape;
5. Agricultural landscape inner polder with dykes on property boundaries - specific New / ReBuild as "cultural" boundaries also as irrigation canals (Green Concrete material irrigation canals covered by translucent photovoltaic panels Energy **Production** & Energy **Consumption** through pumped water irrigation);
6. agrivoltaic properties with trees and specific culture needed solar shading- Solar PV Energy **Production**;
7. Fish-friendly micro hydropower as Solar PV Energy **Storage** & Energy **Production/** Green Hydrogen Production - PV Energy **Consumption**.

[41] https://www.biodiversity-metrics.org/understanding-biodiversity-metrics.html (visited: april 2025).

[42] https://www.grestool.org/ (visited: april 2025).

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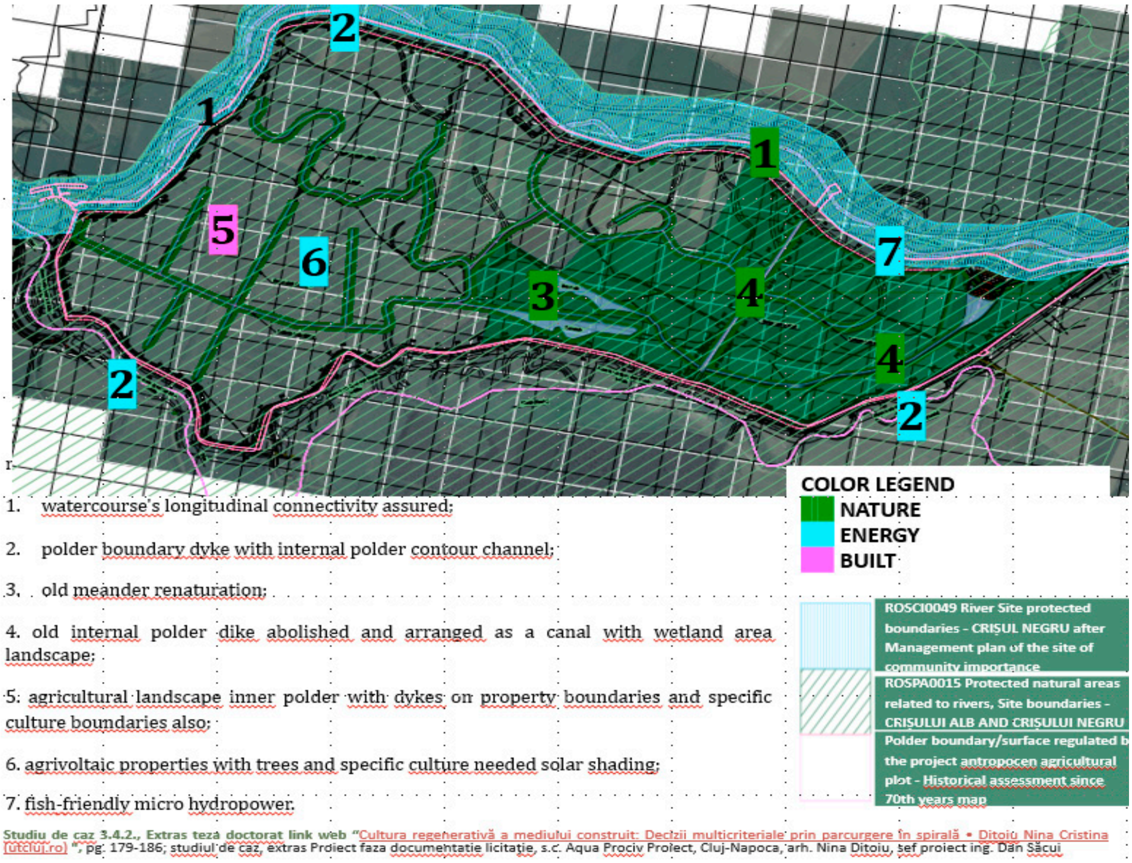

Figure 7. ENERGY & NATURE & BUILT[43].

Figure 7 presents the Zerindu site plan [Z-AR], the support drawing plan with site-protected areas, such as the CRIȘUL NEGRU river, and the pink line representing the polder dikes boundaries. The measures for the three dyads, NATURE-ENERGY-BUILT, were noted as color codes (green, blue, pink) for increased visual visibility.

New ENERGY [Z-AR] Regenerative Dyad "Passive vs. Active"

Table 8 presents the proposal with Energy measures related to the "Passive vs. Active" Dyad.

Table 8. Energy Production / Consumption - Storage.

PRODUCTION[44]	CONSUMPTION - STORAGE[45]
• Solar photovoltaic covering irrigation canals Energy **Production**	• Solar Energy **Consumption** for Green Hydrogen Production
• Agrivoltaics Energy **Production**	• Hydrogen Production as Energy **Consumption**
• Green concrete material irrigation canals with translucent photovoltaic panels covering solar PV production and consumption **through pumped water irrigation.**	
• Fish-friendly Micro hydropower as Solar Energy **Storage** & Energy **Production**	

Agrivoltaics production

[43] *Aqua Prociv Proiect*, Company, Cluj-Napoca, Romania, "Renaturation of Zerind & Tămaşda polders, Arad and Bihor counties" (Romania Team Project: Architecture Concept Sketch - Arch. Nina Cristina Dițoiu; Cad Drawings & Hidrotechnical Design - Eng. Dragoş Gros, Coordinator Eng. Dan Săcui).

[44] Paul Hawken, *Regeneration: Ending the Climate Crisis in One Generation* (Penguin Books: UK, 2021), 198-201, 212-213.

[45] ibidem, 210-211.

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During the 21st century, as Earth's population continues to grow, the demand for food and Energy is also expected to rise. To obtain food, agricultural land will become one of the most sought-after assets on the planet. The trend to generate as much renewable Energy as possible will also need to continue in order to combat climate change and ensure our descendants a more sustainable and climate-neutral future. As an example, calculations performed by the Fraunhofer Institute for Solar Energy Systems (ISE) show that the installed PV capacity in Germany needs to increase by six to eight times by 2045 if the country's energy system is to become climate-neutral[46]. Such figures can be extrapolated everywhere in the world. The proposal to combine land areas from polders used for agriculture with renewable energy production is one way to address food and energy demand concerns together.

As already presented in Table 5 for the ENERGY dyad "Passive *vs.* Active", the renewable energy-related assessment identified agrivoltaics or agri-PV, translucent solar panels on irrigation canals, micro-hydro fish-friendly facilities, and possible smaller-scale green hydrogen production facilities as potential renewable energy production sources. The expected energy consumers might be the agriculture-specific installations needed for growing the crops, like the irrigation pumps, but also the green hydrogen production facilities, if considered.

In some cases, the Energy generated by solar panels could be also used for ensuring the proper treatment for the water used for Irrigation. A research study from Morocco[47] investigated the efficiency of a solar-powered single-stage distillation system for treating domestic wastewater, using heat to vaporise the wastewater, followed by condensation to produce purified liquid water. According to the authors, the system demonstrated increased distilled water production with rising temperatures. A water treatment system like the one mentioned, powered by solar panels, can achieve reductions in parameters like biological oxygen demand, chemical oxygen demand, suspended matter and heavy metals, producing distilled water which can be used for Irrigation even in periods of water scarcity. Solar Energy can be used also for powering desalination systems to attenuate water scarcity[48], where seawater is available. However, the use of domestic wastewater as feed water supply when available outperforms seawater. When the polders are located close to rural villages, using wastewater as feed water supply might be an interesting option to better promote environmental sustainability, while the solar power generation can be further extended by creating rural energy communities using energy resources both from the villages and from the agricultural land plots within the polders.

Additionally, depending on the particularities of the territory or even locality scale of the land used for the polder, there can be also identified solutions for the connections to the power grid, in which case the surplus renewable energy generated inside the polder and inside the rural energy community, if case, might be exported into the rural power grid, while the eventual deficit of Energy might be imported as energy supply from the power grid.

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[46] Fraunhofer Institute for Solar Energy Systems ISE, *Agrivoltaics: Opportunities for Agriculture and the Energy Transition* (A Guideline for Germany: February 2024). https://www.ise.fraunhofer.de/en/publications/studies/agrivoltaics-opportunities-for-agriculture-and-the-energy-transition.html (visited: april 2025).

[47] Said Laasri, El Mokhtar El Hafidi, Abdelhadi Mortadi & El Ghaouti Chahid, *Solar-powered single-stage distillation and complex conductivity analysis for sustainable domestic wastewater treatment* (Environmental Science and Pollution Research: Volume 31, April 2024, pages 29321–29333). https://link.springer.com/article/10.1007/s11356-024-33134-y (visited: april 2025).

[48] El Mokhtar El Hafidi, El Ghaouti Chahid, Abdelhadi Mortadi, Said Laasri, *Study on a new solar-powered desalination system to alleviate water scarcity using impedance spectroscopy* (MaterialsToday: PROCEEDING; March 2024). https://www.sciencedirect.com/science/article/abs/pii/S2214785324001019?via%3Dihub (visited: april 2025).

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Since the PV production is variable, depending both on the location, season, time of day, shading and other variables, to ensure a certain "in-band" production capability for the polder and energy community, if case, the use of storage systems will be also necessary.

It is obvious that renewable Energy requires land area, either if it is solar or wind based. Solar Energy is quite land intensive – for example, for a solar plant of 1 MWp it is necessary a ground area of at least 1 hectare (around 2.5 acres), with no shade. Other older sources consider even larger ground areas of 4-5 acres[49,50] or even 6-8 acres[51] needed for 1 MWp, but since the efficiency of photovoltaic panels increased, the 1ha figure seems more accurate nowadays. Obviously, a better efficiency of the solar panel implies a better utilisation of the land area to generate electricity.

While panels based on regular monocrystalline silicone regularly achieve efficiencies of more than 20%-23%, emerging materials like perovskite, while easier to be produced at a lower cost, can already achieve around 25% efficiency values. Despite their faster degradation and stability issues, perovskite based photovoltaic panels present some interesting features. Unfortunately, perovskites are known to degrade fast in humid areas, or polders are located near riverbeds, where humidity is usually quite high. Also, the first generations of perovskites used in solar panels contained lead, posing additional environmental concerns. Researchers are currently studying different coatings, encapsulation, lead-free configurations and new formulations for the device structure. In such a research work[52], the authors explored complex impedance and modulus over a wide frequency range, process which allowed them to identify certain diffusion, recombination, and ionic transport processes and to observe a correlation between the time constants for each process and the power conversion efficiency (PCE)[52]. During their analysis of lead-free Perovskite Solar Cells (PSC) were revealed intricate dynamics governing their performance[52]. The optimal thickness was identified as a critical factor influencing PCE, while the trends observed in ionic transport, recombination processes, and electronic diffusion showed a delicate balance required to maximise charge transport while minimising recombination losses. The findings[52] emphasised that selecting the appropriate thickness for the absorbing material and recognising the impact of series and shunt resistance in enhancing the efficiency of lead-free PSCs are utterly important steps.

Additional to the specific solar panels selected to be used, the ground area needed for renewable energy production will also have to accommodate the other elements needed to build a PV system such as inverters, cables, single axis mounting systems, tracking systems, access roads, connection to the grid, etc. While solar panels seem to be the better option for agrivoltaics inside polders, it is worth mentioning that compared to solar Energy, the overall average direct impact area for wind parks is around 0.3 ± 0.3 hectares/MW for permanent impact and 0.7 ± 0.6 hectares/MW for temporary impact, meaning that a total direct surface area disruption of about 1.0 ± 0.7 hectares[53] is needed for 1 MW of installed power.

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[49] N.M. Kumar,; K. Sudhakar,; M. Samykano, *Techno-economic analysis of 1 MWp grid connected solar PV plant in Malaysia* (International Journal of Ambient Energy: Vol. 40, No. 4, 2019), 434-443. DOI: 10.1080/01430750.2017.1410226 (visited: april 2025).

[50] Paul J. Saunders, *Land Use Requirements of Solar and Wind Power Generation: Understanding a Decade of Academic Research* (Publisher: Energy Innovation Reform Project, Nov. 2020).

[51] S. Ong,; C. Campbell,; P. Denholm,; R. Margolis,; G. Health, *Land-Use Requirements for Solar Power Plant in the United States* (National Renewable Energy Laboratory, Technical Report NREL/TP-6A20-56290, June 2013).

[52] A. Mortadi,; E. El Hafidi,; H. Nasrellah,; M. Monkade,; R. El Moznine, *Analysis and optimization of lead-free perovskite solar cells: investigating performance and electrical characteristics* (Materials for Renewable and Sustainable Energy: Volume 13, April 2024), 219-232. https://link.springer.com/article/10.1007/s40243-024-00260-z (visited: april 2025).

[53] Paul Denholm, Mohammed Hand, Maddalena Jackson, Sini Ong, *Land-Use Requirements of Modern Wind Power Plants in the United States* (National Renewable Energy Laboratory: Technical Report:NREL/TP-6A2-45834, August 2009). https://docs.nrel.gov/docs/fy09osti/45834.pdf (visited: april 2025).

The previously mentioned estimations are based on the fact that the entire land is used for renewable generation.

While intensive agriculture for ensuring food safety competes for land with renewable energy sources for providing the power, colocation is possible especially for solar power generation by using agrivoltaics (agri-PVs). Given climate change threats, agrivoltaics may reduce inter-annual economic outcome fluctuation due to the frost and high-temperature negative effects on crops by generating economic outcomes through energy production[54]. Using agrivoltaics technology can also provide some benefits for crops as it can create a specific microclimate beneath the solar panels by altering factors like air temperature, relative humidity, wind speed, wind direction and soil moisture. The panels shield crops from both excessive solar radiation and adverse weather conditions like strong rains and hail, potentially also reducing water consumption and stabilising yields during dry years.

One reason to consider perovskite solar panels instead of polycrystalline or monocrystalline silicon ones for agrivoltaic systems is due to their capability to absorb more light of the solar spectrum. Another feature of perovskite panels is that they can be printed on thin, flexibles substrates, the resulting product being lighter and more suitable to be used on the structures appliable for agrivoltaics. Perovskites present also some tunability properties, in the sense that their structure can be tuned for absorbing specific wavelengths of the incident light and that way they can be used for building transparent panels, suitable for covering both irrigation channels and for direct agrivoltaic applications. As a result, for some type of crops, solar panels based on PSCs can be tuned to ensure a certain shade level, optimum for those specific crops. Depending on the shade accepted by different crop types in agrivoltaics, achieving a high efficiency of more than 30% might be possible if using a solar panel combining perovskite and silicon. This can be achieved if perovskite would be tuned to handle one part of the light spectrum, while silicon will handle the other. Even if PSCs are not yet the perfect replacement for silicone and polders are humid, wet and many times both foggy or sunny areas, causing existing PSCs to be less stable and degrade faster over time, research efforts similar to the ones already mentioned[52] will certainly improve upon these drawbacks and will recommend the use of PSCs for agrivoltaic applications, either stand alone or in tandem panels (together with silicone), while their flexibility and tunability for transparency will recommend them in specific architectural configurations for the supporting structures. While PSCs are not quite ready to replace silicon in large-scale agrivoltaics applications today, they show huge promise for greenhouse-integrated PV, low-light crop systems, and future hybrid solutions. With improvements in durability and lead-free options, they could become an excellent choice for agrivoltaic installations such as those proposed to be used inside polders, where low-light crops are easier to be grown due to the specific microclimate.

Since different crops can be grown on the same land, agrivoltaics also support Biodiversity and contributes to climate change mitigation through sustainable agricultural practices[55].

Polders are land plots well suited, especially on their wetlands, for agrivoltaics. That way, polders can be beneficial not only for water management and flood defence but also for conserving Biodiversity and growing certain agricultural crops while generating renewable Energy at the same time.

However, while for solar Energy generated by PV panels located on land plots used only for renewable energy generation the specific values already mentioned for energy production might be

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[54] Widmer J.; Christ B.; Grenz J.; Norgrove L.; *Agrivoltaics, a promising new tool for electricity and food production: A systematic review,* (Renewable and Sustainable Energy Reviews: March 2024). https://ui.adsabs.harvard.edu/abs/2024RSERv.19214277W/abstract (visited: april 2025).

[55] Dr Paweł Czyżak & Tatiana Mindeková, EMBER Empowering farmers in Central Europe: the case for agri-PV *Unlocking the vast potential of agri-PV brings benefits for farmers and energy systems in Central European countries* (Published date: 29.08.2024, Published under a Creative Commons ShareAlike Attribution Licence <CC BY-SA 4.0>). https://ember-energy.org/latest-insights/empowering-farmers-in-central-europe-the-case-for-agri-pv/ (visited: april 2025).

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around 1 MW / hectare or even less, in the case of colocation, when the same land plot is used both for agriculture by growing specific crops, and for energy production, the value of MW / hectare would decrease, but even so, agrivoltaics can increase yields for some specific types of crops, like fruits and berries, by up to 16%[55] Using the land within the plots in this way makes it more efficient thanks to combined electricity and food production.

Within the polders the solar panels will be placed in a way that does not affect significantly the crops - either above crops that benefit from shading, like berries (see Figure 8), or between crops to enable the use of farming machinery (see Figure 9). While in the first case, for fruits and berries, there is instead an increase in yields, in the latter case, the revenues from the sales of generated electricity compensate the reduction in crop yields.

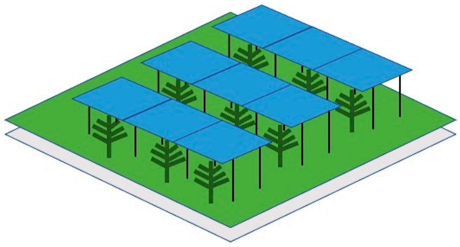

Figure 8. Horizontal PV panels installed for specific crops like orchards, fruits, and berries.

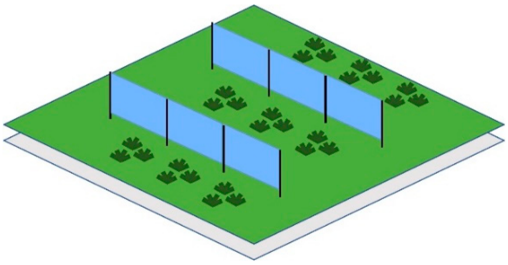

Figure 9. Vertical PV panels installed for specific crops like roots, wheat, oats.

Agrivoltaic systems can range from overhead solar used especially for fruit orchards and berry plantations to interspaced vertical solar between main crops like roots, wheat or oats, in the latter case also allowing access space for farming machinery (tractors, ploughs, etc.).

In overhead agrivoltaic systems, a clearance of sufficient size (usually 2-4 m) ensures adequate space for the plants underneath. In interspaced agrivoltaic systems, row-to-row spacing can exceed 10 m to accommodate farming machinery. Sometimes, inter-spaced agrivoltaic systems might also comprise solar photovoltaic panels (PVP) installed at a certain tilt angle, or even solar trackers, which vary the position of the panels in relation to the sun to optimise both electricity production and crop shading patterns, depending on the crop used.

Usually, agri-photovoltaic (APV) panels are east-west oriented, allowing their daily electricity generation profile to be quite wide compared to south-facing panels. They also exhibit higher efficiencies, even during cooler times of the day.

As a result, even without energy storage added to a polder where east-west oriented APV panels are used, due to their wider generation profile, such systems can be used for grid balancing easier, reducing curtailment and energy exports during the time of day when electricity prices are higher.[55]

Vertical PV systems, used especially for interspaced agrivoltaics, have the added benefit of fully utilising the bifacial features of modern solar panels, reaching capacity factors similar to traditional ground-mounted solar farms, despite an east-west orientation.[55] While apparently colocation of solar Energy and farming seems to decrease the yields in lands, studies[55,56] showed that they can increase

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56 Moritz Laub, Lisa Pataczek, Arndt Feuerbacher, Sabine Zikeli, Petra Högy, *Contrasting yield responses at varying levels of shade suggest different suitability of crops for dual land-use systems: a meta-analysis* (Agronomy for Sustainable

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yields for specific categories of plants, depending on location and weather: crop yields for berries or fruits can increase by 15-16% under 35% shade, compared to an unshaded reference, being a perfect fit for overhead agrivoltaic systems (see Figure 10) and also a perfect candidate for future improved perovskite based or even perovskite combined with silicone based solar panels.

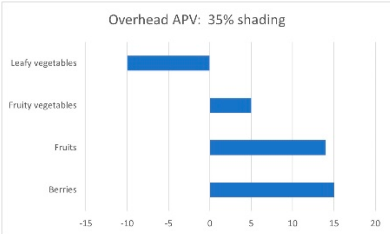

Figure 10. Overhead APV effects on different crops yields, shading 35% [55,56] (facsimile Source of data: EMBER study).

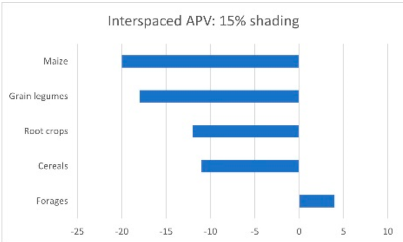

Figure 11. Interspaced APV effects on different crop yields, shading 15%[55,56] (facsimile Source of data: EMBER study).

The EMBER study[55] conducted for Central European countries and published under a Creative Commons ShareAlike Attribution Licence (CC BY-SA 4.0), using data from another research[56] showed that crops such as cereals (e.g. wheat, rye, oats), maise and root vegetables, are more sensitive to shading. The study concluded that with 15% shading, cereals will decrease yield by only 11%, root crops by 12%, and maise by over 20%. By contrary, forages (such as grasses) can increase by 4%. Interspaced agrivoltaic PV system row-to-row spacing of about 10 m limits the shading to between 10% and 20% and could combine all those crops, ensuring at least a level of 80% crop yields compared to a reference (see Figure 11). Even though the yields of different types of crops can be reduced, one significant advantage of agrivoltaic systems resides in their higher productivity, resulting from the combined production of food and electricity, meaning that the efficiency of land use is significantly increased compared to the use of land just for farming or just for producing renewable Energy.

Land use efficiency is measured as the sum of solar electricity generation compared to a traditional ground-mounted solar farm plus the crop yield compared to an unshaded reference[55]. Depending on the crop type, the results can reach 170-180% for berries, fruits and fruity vegetables and 110-130% for root vegetables, cereals and forages. Even the least shade-tolerant crop, maise, reaches 104% land use efficiency, showing that agrivoltaics will be more productive than the traditional approach of separating ground-mounted solar and farmingError! Bookmark not defined.. A synthetic view of the land use efficiency for different types of crops is illustrated in Figure 12:

Development: Volume 42, June 2022). https://link.springer.com/article/10.1007/s13593-022-00783-7 (visited: april 2025).

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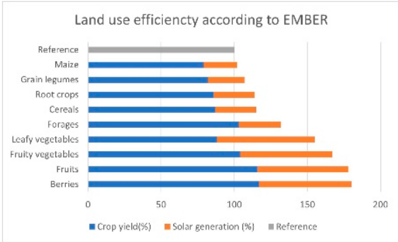

Figure 12. Land use efficiency for different types of crops[55] (facsimile Source of data: EMBER study).

Agrivoltaic solar generation varies depending on multiple parameters, including height, row spacing, tilt, geographic location, panel orientation, transparency, bifaciality ratio, and tracking. The relative generation compared to a traditional solar farm ranges from 25% for interspaced agri-PV to 63% for overhead agri-PV.

The lower solar generation is predominantly because less solar capacity can be installed per hectare. Considering a capacity of 1 MW per hectare is assumed for traditional solar farms, agrivoltaic systems can achieve capacities ranging from 0.3 MW/ha to 0.7 MW/ha[46], as confirmed by shading analysis performed using the *AGRIPV tool* developed by the KU Leuven University from Belgium[57]. Capacity factors were calculated during the study[55] conducted for Central European countries using the Python package for calculating renewable power potentials and time series *Atlite*[58], assuming bifacial east-west vertical panels for interspaced agrivoltaics and 15 degrees tilted east-west for the overhead system.

The EMBER study[55] also showed that the capital expenditure (CAPEX) for agrivoltaic projects is significantly higher than for traditional ground-mounted solar farms due to the particularities of the mounting system.

An estimate of the levelized cost of electricity (LCoE) over twenty years shows that overhead agrivoltaics (with clearance heights of 2.1/2.5 to 4 m) can be approximately 40% more expensive than ground-mounted PV systems. In contrast, for interspaced agrivoltaics, this increase is only about 11%. However, both agrivoltaic systems are considerably cheaper (40-50%) than rooftop solar used in regular households or industrial projects.

Romania shares many similarities with countries in Central Europe regarding the specificities of agrivoltaics, intended to avoid energy demand competing with food demand for land use. Even if a Romanian case was not considered in the EMBER[55] document, other research papers have studied the agrivoltaics' potential of the country. One such example[59] is analysing a case study for a land plot of approximately 16.2 hectares located in southeast Romania, used for cereal production (mainly wheat), with an average productivity of 2.74 t/ha/year. The region is known for its flatness, and the land plot that was analysed also has a maximum slope of 2 degrees, making the installation of PV mounting structures easier and less expensive compared to other terrains.

The scenarios analysed were one in which bifacial monocrystalline PV modules adding up to 8.58 MWp were considered to be installed vertically in the interspaced APV configuration, a second one in which the panels were installed in the overhead APV configuration on a fixed mounting structure at a 30-degree tilt angle, calculated so that the modules would not shade the crops over a specific period of time, adding up to 13.2 MWp, and the reference scenario was considered for conventional PVP with a 30-degree tilt, adding up to 23.1 MWp.

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[57] https://iiw.kuleuven.be/apps/agrivoltaics/tool.html (visited: april 2025).

[58] https://github.com/PyPSA/atlite (visited: april 2025).

[59] Cristian Gheorghiu, Mircea Scripcariu, Gabriela Sava, Miruna Gheorghiu, Alexandra Lidia Dina, *Agrivoltaics potential in Romania–A symbiosis between agriculture and energy* (EMERG, Volume VIII, Issue 3/2022 ISSN 2668-7003, ISSN-L 2457-5011). https://emerg.ro/wp-content/uploads/2022/10/9-AGRIVOLTAICS-POTENTIAL-IN-ROMANIA-—-A-SYMBIOSIS-BETWEEN-AGRICULTURE-AND-ENERGY.pdf (visited: april 2025).

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Based on the quotations received from the local market, the research[59] showed that an average specific cost for developing the project was around 850 EUR/kWp for the conventional PVP scenario, 950 EUR/kWp for the interspaced APV scenario and 1,300 EUR/kWp for the overhead APV scenario, figures which are roughly quite similar to the ones mentioned in the EMBER[55] study.

The research[59] performed a technic-economic analysis based on the Net Present Value (NPV), the Internal Rate of Return (IRR), the Simple Payback Period (SPV) and the Benefit-Cost Analysis. The analysis has been performed for a 25-year lifetime of the investment and used input data such as the discount rate (14%/year), the export electricity price (considered for Romania as 90 EUR/MWh, taking all relevant markets into account, such as the Day Ahead, Intra Day and the Balancing Market) with a specific escalation rate (7.5% / year), the wheat price (330 EUR / ton) and its escalation rate (2.5% / year).

The analysis (BAU or Business As Usual) has considered a fourth scenario for exploiting the land only for agricultural purposes.

Table 9 shows some of the financial results of the study[59]:

Table 9. (Source of data: from the referenced paper).

Scenario	NPV (EURO)	IRR (%/year)	SPP (years)	BCA (-)
BAU	23,327	37	4.38	1.25
Interspaced APV	1,914,339	17	8.38	1.22
Overhead APV	4,632,501	17	8.20	1.26
Conventional PVP	18,287,612	23	6.12	1.86

According to these findings, for specific input data which are also dependent on local market conditions, the NPV, IRR and SPP values for a conventional PVP project are significantly better than for the two agrivoltaics scenarios, while between the two agrivoltaics scenarios, the overhead APV one provides better values than the interspaced APV one.

The conclusion is that a conventional PVP project will be more profitable than an APV project.

However, since agricultural land is essential for ensuring food safety, to preserving the agricultural function of the land, legislators should act in the sense to limit the use of land only for energy production, or encourage through incentives the use of agrivoltaics systems to generate both food and electricity, or to use both approaches simultaneously. A more focused approach might be to enable agricultural companies or agricultural cooperatives to have access to financing toward implementing agrivoltaic projects from which those companies might benefit directly for the needs of growing their crops (like Irrigation, water treatment, if case, running electric farming machinery, different processing stages requiring power etc.).

The previously mentioned Romanian research paper[59] estimated, depending on location and crop type, an average need of 4,260 m^3 of water for each hectare of arable land required for Irrigation, which implies a demand of around 1.2 MWh/ha/year for electricity needed for water extraction and pumping. At the same time, if using electric farming machinery, their need for power consumption might also be ensured by the renewable Energy produced on-site if properly configured. If the grown crop is wheat, the arable land would need a minimum of three farming machinery passes per year[59] – the first for preparing the soil for seeding, the second for seeding and the final for harvesting the crop. Considering that the farming machinery are electric vehicles (e.g., tractors, ploughs, combine harvesters etc.) and their power consumption might be around 80 kWh/100 km, respectively around 0.8 kWh/ha/pass, this adds up to a power consumption of only 2.4 kWh/ha/year[59] for the farming machinery.

Even if considering it an order of magnitude more significant, the value (0,024 MWh/ha/year) remains still small compared to the power needed for Irrigation (1.2 MWh/ha/year), adding to a total of 1.224 MWh/ha/year. Since the interspaced APV configuration analysed in the mentioned paper[59] has been estimated (using PVSyst) at an energy production of around 6,670 MWh/year, it can be seen

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that even this less efficient configuration does ensure a power production capability to provide power for several thousands of hectares of agricultural land. The overhead APV system energy production was estimated at more than double compared to the interspaced APV system, more exactly at 13,200 MWh/year, providing a much larger power reserve in the land plot.

In Romania, the installed capacities in PVP are intended to be increased by 3,665.84 MW in the near future[59,60]. Considering the required land mass for 1 MWp conventional PVP as 1 hectare, the increase in capacity will need at least 3,666 ha of land. Romania has a good solar potential for developing PVP projects, with solar irradiance values ranging between 1,000 to even more than 1,350 kWh/m2/year[59], depending on the location. However, the agricultural potential of Romania overlaps in many areas with the solar potential map, meaning that the most profitable solar parks will have to compete with land plots with significant agricultural production capacities.

Polders are land plots which are usually considered for water defence and management purposes, where conventional PVP are not suitable to be installed, because some areas can be intentionally or non-intentionally flooded, so in this case the fact that both APV solutions are less profitable than conventional PVP configuration is less relevant. As a result, the idea to use agrivoltaics for such zones, which otherwise wouldn't be used at all for solar production, allows a very constructive coexistence between energy production and agriculture, even if the capacity factors are significantly smaller, depending on the selected APV system, compared to conventional PV systems.

Obviously, since portions of the land in polders are intentionally flooded sometimes, the APV system which best suits such land plots is the overhead one, its construction structure allowing the exposed parts of such a system to be never flooded.

For the Zerindu [Z-AR] polder (more precisely for a specific plot at latitude 46.638291° and longitude 21.565599°), where the land can be used both for Biodiversity and agricultural production plus energy production through agrivoltaics, this research considered the simulation of around 1 MWp overhead APV system installed on the plot by using 180 rows of around 24 m length resulting in a total of 1,800 bifacial solar panels of 560 Wp (having a bi-faciality factor of around 80%), installed at 2.2 meters above the ground using a light structure to pose less shade on the crop. This configuration results in a land plot use as shown in Figure 13 of 16,584 m^2 for about 1 MWp, or roughly around 1.7 ha for 1 MWp, which is higher than the land use for traditional PV systems (1 ha for 1 MWp), meaning that the overhead APV land use for energy production is about 58% compared to the land use for energy production of a traditional PV system. This value resulted considering only the agrivoltaics PV panels for the necessary land use, but if adding the other necessary element (connection cables, access ways, cabinets, inverters, etc.) this value will decrease even further. The necessary land surface has been determined according to the example shown in Annex 4 of the French Government Instruction technique DGPE/SDPE/2025-93 regarding "Application of the regulatory provisions relating to ground-based photovoltaic and agrivoltaic installations in natural, agricultural and forest areas"[61].

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[60] Integrated National Energy and Climate Plan of ROMANIA, (2021-2030 Update, First draft version). **https://commission.europa.eu/**system/files/2023-11/ROMANIA%20-%20DRAFT%20UPDATED%20NECP%202021-2030.pdf (visited: april 2025).

[61] Gouvernement de France: Ordre de méthode, Bulletin official: Instruction technique DGPE/SDPE/2025-93 (Objet: Application des dispositions réglementaires relatives aux installations agrivoltaïques et photovoltaïques au sol dans les espaces naturels, agricoles et forestiers). https://info.agriculture.gouv.fr/boagri/instruction-2025-93 (visited: april 2025).

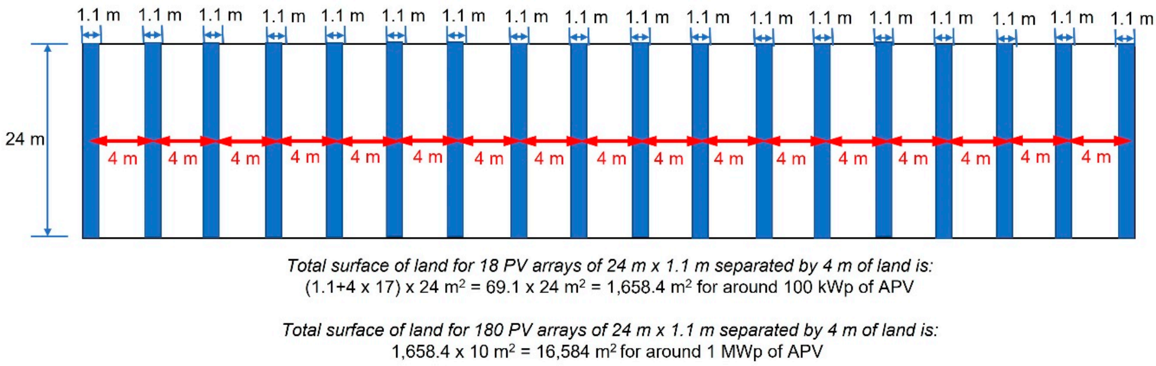

Figure 13. [Z-AR] Land plot surface used for overhead APV.

The proposed APV system orientation is east-west, and the tilt angle is 15 degrees, while the module transparency is 40%. The behaviour of the APV system has been simulated using the *AGRIPV* web tool[57] developed by the KU Leuven University from Belgium as part of a Horizon 2020 project (however, considering a system ten times smaller, with only 18 rows of overhead APV panels instead of 180 rows, due to simulation limitations).

The specific energy yield resulting from the simulation for the berries crop is 1,256.58 MWh/MWp/year, while the monthly distribution of produced Energy is shown in Figure 17.

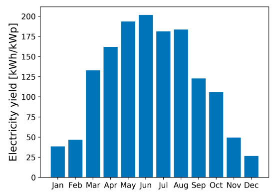

Figure 14. [Z-AR] Monthly distribution of specific solar yield in the polder (extracted from the simulation report).

If comparing the specific energy yield resulted from the *AGRIPV* simulation for the configuration proposed, the value of 1,256.58 MWh/MWp/year is quite comparable to the specific value of 1.576,89 MWh/MWp/year resulted from the PVSyst simulation performed as part of the study in Ialomița county[59], validating the overall approach for the similar APV configuration proposed here. The rather small difference is explainable due to the different locations and incident sunlight as well as other specific configuration parameters (type of panel, efficiency, tilt angle, etc.).

According to the simulation tool's notes, it uses the weather data input based on Typical Meteorological Year data format (TMY) collected from PVGIS (2006-2016)[62], the albedo of the field is fixed at 0.3, the tracking angles are limited from -50° to +50° and a backtracking algorithm is active to minimise row-to-row shading, the crop simulations are based on relative crop yield curves[56] and only the shade caused by the PV modules is simulated in detail. For the shade caused by the support structure, the tool uses fixed parameters.

The remaining PAR percentage represents how much Photosynthetically Active Radiation (PAR) still reaches the crops on average compared to a reference area without agrivoltaics – this value has been estimated by the web tool to be around 83%.

In the context of growing berries, respectively fruits on the land plot considered in the polder, the relative crop yield (compared to a reference land without solar) is shown in Figure 15.

[62] PHOTOVOLTAIC GEOGRAPHICAL INFORMATION SYSTEM. https://re.jrc.ec.europa.eu/pvg_tools/en/ (visited: april 2025).

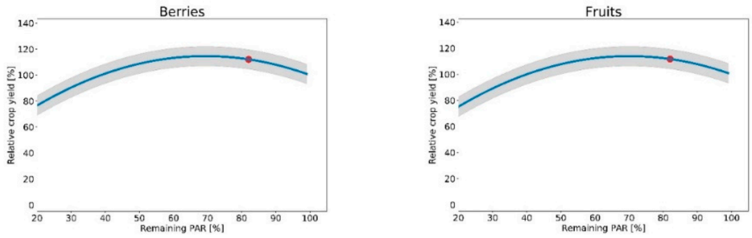

Figure 15. Z-AR] Relative crop yield vs remaining PAR in the polder for berries and fruits (extracted from the simulation report).

It is worth mentioning that for the calculated remaining PAR of 83%, the relative crop yield is 112% for berries, meaning that in the presence of overhead APC, for specific crops like berries, the yield is greater than in the absence of shading from the overhead APC, making crops like berries suitable for being grown in the polder. A similar simulation shows that for fruit orchards, the relative crop yield at a remaining PAR of 83% is 111%, almost identical to that of berries. These simulation results confirm the findings from the EMBER[55] study in a qualitative sense, because for fruits and berries a certain level of shade leads to an actual increase in the yield. Quantitively, for 83% of the light reaching the crops, their yield increases to 111-112%.

Since the relative crop yields are significantly lower for root crops, the access of farming machinery on wetlands as the ones in the polders is more difficult due to the Nature of the soil and the interspaced APV systems would be prone to flooding, in the polders the growability of root vegetables has been considered less suitable than berries or fruit orchards, which can be more easily grown on lands with collocated overhead APV systems whose structures makes them less prone to flooding.

For berry and fruit orchards, the power consumption of any specific machinery used inside the polders will be negligible compared to the power produced, meaning that the Energy generated in the polders will be usable mainly for Irrigation. Since the polders do usually have enough space to extend the overhead APV systems, the installed peak power might be expanded significantly to approach also other possible energy-intensive applications like small-scale green hydrogen electrolysis using water taken from the river near the polders, if the prerequisite conditions for water use and consumption might be met. Additionally, if the water used for Irrigation uses wastewater as input source and needs treatment, the distillation process could be also powered through solar Energy. If the local grid conditions allow, the overhead APV systems to be used together with berries or fruit production on the same land plot might also be connected to the grid, serving local communities or exporting the surplus power further into the grid.

Photovoltaic covering irrigation canals.

Originally developed to address water loss by reducing evaporation in agricultural regions, the panels covering irrigation canals evolved into canal-covering technologies in the late Anthropocene.

The technology is adapted for areas with extensive irrigation networks, mainly where traditional water management systems require modernization without complete reconstruction, and for aquatic Biodiversity, translucent photovoltaics were chosen.

Agricultural communities, such as those in polders, became Energy & Agricultural communities. This can also introduce unique, adapted design modalities that better fit local farming practices and/or traditional irrigation patterns.

Semi-transparent photovoltaic panels, designed for covering irrigation canals, are recommended in arid areas, as [Z-AR], but are not for sure recommended for covering meanders re-naturated to increase Biodiversity.

Implementing translucent solar panels is transforming water management in agriculture while generating green Energy. These panels reduce water evaporation from covered canals, thereby

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conserving water in agricultural regions that are vulnerable to severe drought. Reduced evaporation and algae growth in the covered canals have improved water quality.

The electricity generated supports the local farming community, which becomes an energy community while maintaining traditional farming practices that a family can implement on a specific rural plot of indigene traditional landscape design.

At the same time, as will be noticed in Figure 16 with a replicability study in Tămaşda polder, Bihor county, NATURE area for BIODIVERSITY is not similar to the ENERGY area, where this kind of covered irrigation channels appears.

Solar storage potential

Solar storage could include green hydrogen production and fish-friendly micro hydropower, but a more detailed technical design is needed to be implemented in a future design proposal. The Dyad related to ENERGY may examine various approaches to solar energy storage in agricultural settings, as in Figure 17.

A fish-friendly micro-hydro power plant associated with a lateral dam or water reserve area near the watercourse could be considered for one of the two discussed polders. However, this research stage analyses the possible and desirable aspects without detailing technical solutions, focusing solely on the potential for green hydrogen production and the potential of fish-friendly micro-hydropower systems.

The study includes more of a list than lists and technical specifications. It analyses the potential, rather than the feasibility, of green hydrogen production for implementing fish-friendly micro-hydropower systems without detailing technical solutions or specifications for different storage methods.

Figure 16 is a concept sketch of the study case [Z-AR] Zerindu polder, Arad county, and the related replicability case study - Tămaşda polder, Bihor county, with measures noted, both on Crişul Negru river.

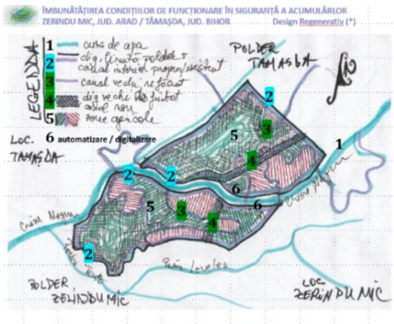

Figure 16. [Z-AR] Ditoiu, N.C.'s sketch, replicability case study - Tămaşda polder, Bihor county & Study case - Zerindu polder, Arad county: planimetric sketch, Polders Zerind & Tămaşda Sketch[63], the two polders with solving related to the legend. 1. watercourse; 2. polder boundary dike with inner polder contour channel; 3. old rehabilitated canal; 4. old pier inside the polder dismantled and arranged as a canal/wetland; 5—inland agricultural land for polders 6. Biodiversity /water level digitalisation.

[63] Dițoiu Nina Cristina's concept sketch, coordinator Aqua Prociv Proiect team Eng. Dan Săcui. "Renaturation of Zerind polder, Arad county" & " Renaturation of Tămaşda polder, Bihor county"

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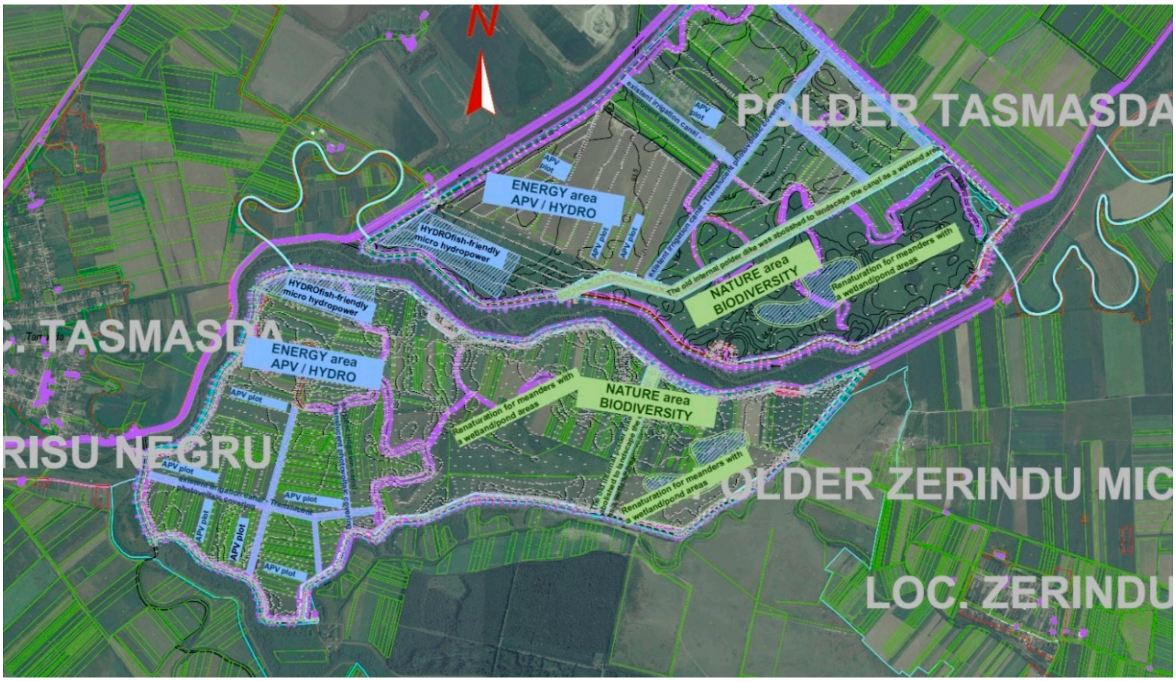

Figure 17. Replicability study case - Tămaşda polder, Bihor county, and study case – [Z-AR] [15]Zerindu polder, Arad county, with the same proposed measures:.

- *ENERGY AREA: APV plots, fish-friendly micro-hydropower, and existing irrigation canal—transparent photovoltaic covering;*
- *NATURE AREA: Renaturation for meanders with wetland/pond areas. The old internal polder dike was removed to transform the canal into a wetland area.*

Discussions

The practical main findings on integrating traditional agricultural approaches with modern renewable energy systems primarily focus on the case studies of the traditional residential plot [S-SV] Boroaia, Suceava county, and the related agrarian plots in Polderul Zerindu Mic, Arad county [Z-AR], with a replicability in Tămaşda older, Bihor county. The gaps that need to be closed relate to the Dyads involving the Solar Regeneration Monad, the holistic design, and the Humanistic versus Technical approach.

Table 10. Evaluation with a similar SWOT method.

Strengths	**Weaknesses**
Technical:	**Technical:**
• BUILT - Natural areas related to the population contribute to the **well-being** of tourist attraction points; **Bioregions**[64] **built heritage;** successfully integrating agrivoltaic systems with traditional agricultural practice preserving cultural heritage.	• NATURE - EU Taxonomy hydropower restrictions; Lack of studies on **an agricultural registry**[70]; Failure to capitalise on existing opportunities related to NbS[2], Biodiversity.

[64] Paul Hawken, *Regeneration: Ending the Climate Crisis in One Generation* (Penguin Books: UK, 2021), 84-85, 88-89, 96-99, 198-201, 210-213.

[70] similar to Apur document about Seine Valley-Agricultural and food dynamics: Vallee de la Seine, enjeux & perspectives, Dynamiques agricoles et alimentaires, Coopération des agences d'urbanisme APUR, AUCAME, AURBSE, AURH, L'INSTITUTE, Vallée de la Seine, contrat de plan inter-régional État-Régions Vallée de la Seine, 2021.

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- NATURE - Wetland with biodiversity impact/ carbon storage impact; Biodiversity, Biocapacity vs Ecological Footprint[65] Wilding – Wetlands, Land – Regenerative Agriculture[64].
- ENERGY - Enhancement of the role of **hydro-technical** arrangements through maintenance measures: avoiding damage to social and economic objectives by mitigating floods, providing water reservoirs for water supply to various areas, and generating electricity; Similar solar cadastre as solar PV potential proposal[66]; Energy – Solar, Energy storage, Microgrids[64].

Humanist:

- NATURE - *P. Kindel's* **biomorphic urbanism** principles in design[67].
- BUILT - **Circular metabolism**'s[68] implementation with Carlos Tapias's humanist measures[69].

- BUILT - Failure to capitalise on existing opportunities related to cultural landscape, potential resistance to change from local communities.
- ENERGY - Failure to capitalise on existing opportunities related to **green wave, and energy transition**[71].

Humanist:

- ENERGY - Christopher Alexander's "**Order as Mechanism**": "It is almost impossible to view a Mozart symphony as a machine with certain kinds of behavior[72]".
- BUILT - The lack of Aristide Athanassiadis's circular metabolism[12] implementation with Carlos Tapias's humanist measures[69] **lacks** "**circularity strategies** (...) formulated and implemented[73]".

Opportunities

Technical:

- NATURE - Blue-green corridor development promotes native species and increases

Threats

Technical:

- ENERGY - Financing issues; Timely synchronization of measures among all involved actors.
- NATURE - the impact of climate change and the environmental impact of potential applications, including photovoltaics,

[65] David Lin, Laurel Hanscom, Adeline C Murthy, Alessandro Galli, Mikel Cody Evans, Evan Neill, Maria Serena Mancini and others, *Ecological Footprin Accounting for Countries: Updates and Results of the National Footprint Accounts, 2012-2018* (MPDI Resources: September 2018, 7(3):1-22, License CC BY 4.0).

[66] CADASTRE SOLAIRE 2.0, note no. 148, april 2019, APUR (atelier parisien d'urbanisme) Directrice de la publication: ALBA, Dominique, Note réalisée par: Gabriel SENEGAS, Sous la direction de : Olivier RICHARD, Cartographie et traitement statistique: Apur, www.apur.org. https://www.apur.org/fr/nos-travaux/vers-un-cadastre-solaire-2-0 (visited: april 2025).

[67] Peter J. Kindel, *Biomorphic Urbanism: A Guide for Sustainable Cities* (Why ecology should be the fondationa of urban development: Medium SOM, Apr 2019). https://som.medium.com/biomorphic-urbanism-a-guide-for-sustainable-cities-4a1da72ad656 (visited: april 2025).

[68] Aristide Athanassiadis, https://www.circularmetabolism.com/ (visited: april 2025)

[69] Carlos Tapia, Marco Bianchi, Mirari Zaldua, Marion Courtois, Philippe Micheaux Naudet, Andrea Bassi, Philippe Micheaux Naudet and others, CIRCTER - Circular Economy and Territorial Consequences (ESPON: Applied Research, Final Report, 09.05.2019), 7. https://circulareconomy.europa.eu/platform/sites/default/files/circter_fr_main_report.pdf (visited: april 2025).

[71] https://www.hydrogrid.ai/g-resources/resilience-in-hydropower-operations?utm_source=p[?]m=hydro-review&utm_campaign=resilience-hydropower-whitepaper (visited: april 2025).

[72] Christopher Alexander, *The Nature of Order: An Essay on the Art of Building and the Nature of the Universe-The Phenomenon of Life* (Center for Enviromental Structure, Berkeley, California, 2014, first ed. 1980), 15.

[73] Carolin Bellstedt, Gerardo Ezequiel Martín Carreño, Aristide Athanassiadis, Shamita Chaudhry, *METABOLISM of CITIES* (CityLoops-D4.4–Urban Circularity Assessment Method, Version 1.0 <2022-05-31>), 35. https://cityloops.eu/fileadmin/user_upload/Materials/UCA/CityLoops_WP4_D4.4_Urban_Circularity_Assessment_Method_Metabolism_of_Cities.pdf (visited: april 2025).

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biocapacity[74], Biodiversity, and Wildlife Corridors as part of Green Infrastructure[75].

- ENERGY - Digitalisation is necessary to develop energy grids that incorporate renewable energy production and achieve balance through storage and dam management; Assessment of **green hydrogen production**; **Photovoltaic energy production** Agrivoltaics; **Hydropower** energy production environmental impact technologies - fish-friendly turbines micro hydropower [76]; Relevant contribution to the "**green wave**" measures and **energy transition**[77,78].
- BUILT - Relevant cultural heritage elements of the wider area and specific enhancement measures. Human Well-being [79] extends the approach to other regions and the possibility of developing new technological solutions that better integrate with traditional practices

Humanist:

- BUILT - "Beauty Project: A manifesto"[80], "**Pretty is never enough. Useful is never enough.** (...) Design can create beauty for everyone, hydropower, and hydrogen production, must be assessed.
- BUILT - Population options about Development of Agricol / Energetical Communities, loss of Indigenous Knowledge

Humanist:

- ENERGY - *M. Heidegger's* standing - reserved form, related to technology implementation after a "very insistent asking for delivery" [83,84] vs Neil Leach's "sacrifice as a form of vitalization" [85]
- BUILT - "Beauty Project: A maniffesto"[86], "We like what we know"; *David Seamon's* Place-Making and relevance of" place identity[87] with the threats in "Identity" vs "Sustainability." [81]

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[74] https://commons.wikimedia.org/wiki/File:World_map_of_countries_by_ecological_deficit_(2013).svg (visited: april 2025).

[75] Erica Honeck, Arthur Sanguet, Martin A. Schlaepfer, Nicolas Wyler, Anthony Lehmann, *Methods for identifying green infrastructure* (SN: Applied science 2020). https://link.springer.com/article/10.1007/s42452-020-03575-4 (visited: april 2025).

[76] https://www.turbulent.be/projects (visited: april 2025).

[77] https://www.hydrogrid.ai/g-resources/resilience-in-hydropower-operations?utm_source=p[?]m=hydro-review&utm_campaign=resilience-hydropower-whitepaper (visited: april 2025).

[78] Peter Droege, ed., *URBAN ENERGY TRANSITION Renewable Strategies for Cities and Regions* (Elsevier, 2018), 31-49, 85-113.

[79] Erica Honeck, Arthur Sanguet, Martin A. Schlaepfer, Nicolas Wyler, Anthony Lehmann, *Methods for identifying green infrastructure* (SN: Applied science 2020). https://link.springer.com/article/10.1007/s42452-020-03575-4 (visited: april 2025).

[80] Stefan Sagmeister, Jesssica Walsh, *Sagmeister & Walsh – Beauty* (Book: Phaidon Press Ltd, ISBN 9780714877273, Nov 2018, London), 269.

[83] Martin Heidegger, *Întrebarea privitoare la tehnică*, in: *Originea operei de artă*, translated by Gabriel Liiceanu after: *Die Frage nach der Technik* (Vortrage und Aufsatze, Teil I, Neske, Pfullingen, 1967), 120-169. (reprint, Bucharest: Humanitas, 2011), 134.

[84] Martin Heidegger, *The Question Concerning Technology* (Basic Writings: Martin Heidegger, Ed. David Farrell Krell, New York: Harper Collins, 1993), 311-341.

[85] Neil Leach, *Uitati-l pe Heidegger/Forget Heidegger* (bilingv, Ed. Paideia, Bucuresti, Romania, 2006, translated by Magda Teodorescu, Dana Vais), 33-34, 66.

[86] Stefan Sagmeister, Jesssica Walsh, *Sagmeister & Walsh - Beauty* (Book: Phaidon Press Ltd, ISBN 9780714877273, Nov 2018, London), 25.

[87] David Seamon, *Place, Place Identity, and phenomenology: a triadic Interpretation based on J.G. Bennett's Systematics* (The Role of Place Identity in Perception, Understanding, and Design of Built Environments, Editors: Hernan Casakin and Fatima Bernardo, Bentham Science Publishers, 2012).

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everywhere."; *David Seamon's* **Place-Making Opportunity**[81]
- NATURE - "The invention of the rivers" as "**Waters of Eden**" after a "River colonialism" [82]

The need for a balance between Technical and Humanistic perspectives and between Energy and Nature is crucial. This discussion highlights the differences in the interdisciplinary authors' team. There are also precise measurements needed, such as accurate figures in energy production or budgeting, and the importance of preserving Biodiversity, which can be accounted for through biodiversity credits or carbon credits as part of the same budget. Additionally, the topic encompasses the concept of double materiality, a widely discussed concept internationally. Understanding the reasons that drive the need for a taxonomy with environmental DNSH principles, the Knowledge vs Understanding spiral that expands and contracts scales and metrics in Nature, Energy, and Built environments, involving relevant multidisciplinary experts, is about conquering Understanding through multidisciplinary Knowledge. There is no single best option. It is about making compromises, rechecking, and reviewing the spiral as often as necessary. In particular cases, the technical design should be developed to apply any other necessary measures related to Built/heritage or Nature/Green, trees, or Nature/Biodiversity risks. The method was demonstrated in a particular water-related environment and explained the need to solve Energy-related risks following the other crucial issues in Nature & Built, which needed to be achieved, at least after the DNSH principles.

The discussions will follow a technical approach related to other necessary studies. The case study is more about the conceptual design stage, proposing to achieve essential Energy without ignoring Nature or Built goals. It is so relevant for this preliminary design stage, when it is opportune to implement other goals, not just for solar Energy, that in the final stages, it will not be possible or at least more foreseeable if ignored from the beginning a proper conceptual design.

Conclusion

David Seamon's Place Monad, accepted in the Place Petal of the Living Building Challenge regenerative system, was inspiring as a Bennettțs methodology. Another assumed date-in is European taxonomy with DNSH (Table 2) principles applied to Energy/ Water/ Recyclable, Mitigation (water floods), and Adaptation (renewable Energy) environment Criteria. The spiral concept is the framework model, a holistic management of many distinct criteria in a more creative, double-way, visual spiral as a methodology needed and affiliated with design work. The framework can be assimilated into the concept phase of any built design work, on any design scale, from Object - building to Territory - water course landscape.

The fundamental relationships explored in the Dyads related to the double-way Spiral methodology are Technology vs Tradition (Nature), Technical vs Humanistic (Built), and Active vs. Passive (Energy). Each Dyad can effectively combine traditional Knowledge and modern technological solutions to create sustainable and culturally appropriate systems. In conclusion, a similar SWOT (Strengths, Weaknesses, Opportunities, Threats) analysis assesses the technical and humanistic aspects of the studied systems. The technical strengths identified include successfully integrating agrivoltaic systems with traditional agricultural practices and efficient water

[81] David Seamon, *Place, Place Identity, and phenomenology: a triadic Interpretation based on J.G. Bennett's Systematics* (The Role of Place Identity in Perception, Understanding, and Design of Built Environments, Editors: Hernan Casakin and Fatima Bernardo, Bentham Science Publishers, 2012).

[82] Dilip da Cunha, *The Invention of Rivers: Alexander's Eye and Ganga's Descent* (Publisher: University of Pennsylvania Press, Philadelphia, Feb 2019) *(chapter Waters of Eden), 123-136. (describes four rivers sourced in paradisep), 126. (the city manipulates only the earth surfacep), 155, 273-294. (After rivers (...) extreme hydraulic engeneering), 290.*

management through modernized older systems. The technical weaknesses focus on the higher initial costs and the complexity of implementing hybrid systems.

The final similar SWOT analysis of the humanistic side, strengths include preserving cultural landscapes and traditional agricultural Knowledge, while weaknesses include potential resistance to change from local communities. Opportunities highlighted in the SWOT analysis include the potential for extending these approaches to other regions and the possibility of developing new technological solutions that better integrate with traditional practices. Threats are examined from both technical and humanistic perspectives (such as the impact of climate change and the loss of indigenous Knowledge).

The primary conclusion pertains to cultural traditions and local approaches that can form energy solutions and technologies. The study explicitly examines agrovoltaics and the integration of solar Energy into traditional agricultural practices. A case study of a polder (hydro-technical work, temporary non-permanent dam limited by dikes) is presented, demonstrating how environmental challenges, risk management and the transition to renewable Energy can be addressed while preserving a cultural landscape - an Anthropocene polder through a vernacular traditional similar family plot landscape design. The research highlights the importance of traditionally inspired design as replicability that assumes local acceptance in relation to historically studied ethnographic support, as the Built, underscoring the need to balance technical and humanistic approaches and the importance of Energy & Nature principles after DNSH. The research aims to demonstrate the replicability of the holistic framework in related design-built, the Double-ways Spiral design framework, and also the replicability of the solar energetic community [Z-AR] polder researched area, the Romanian Agricultural wetlands.

The future gaps that need to be closed are the solar regenerative monad with its dyads to be implemented in distinct built environments, the Built—new BIPV focus on Built—Heritage on a larger scale or Built—new BIPV in a new energetic community, and the Nature—Blue - Green watercourse works.

The main research weakness is the lack of technical studies, which represent only a concept for a preliminary design that can be assumed in the subsequent design stage of a more detailed technical design project. The following to be researched, the Solar Regeneration monad is related to the visual holistic framework for new study cases and also related to the study cases detailed, Energy dyad — solar agrivoltaics supported with technical studies, the detailed stage.

Acronyms

[DNSH] Do No Significant Harm; [NBS] Nature Based Solutions;

[N] Nature; [E] Energy; [B] Built; [O] Object; [L] Locality; [T] Territory; [G] Global;

[S-SV] Săcuţa locality, Boroaia, Suceava county, Romania; lat. 47313130° N, long. 26283486° E, +423m;

[Z-AR] Zerindu Mic polder, Arad County, Romania; lat. 46641100° N, long. 21586112°E, +92m.

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40. Gouvernement de France, Ordre de méthode: *Instruction technique DGPE/SDPE/2025-93* (Objet: Application des dispositions réglementaires relatives aux installations agrivoltaïques et photovoltaïques au sol dans les espaces naturels, agricoles et forestiers).