wennovate

D5.3 Joint long-term programme plan (incl. Resource and Activity allocation plan)

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WEnnovate partners

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Executive Summary

This document, *D5.3 Joint Long-Term Programme Plan (including Resource and Activity Allocation Plan)*, represents a cornerstone deliverable of the WEnnovate project and is intended to complement *D5.2 National Action Plans*. While *D5.2* identifies key opportunities and strategies for advancing the digital energy transition at the national level in Slovakia, the Netherlands, Hungary, and Ukraine, this Joint Programme Plan focuses on areas of overlap, synergy, and collaborative potential among WEnnovate partner countries and across the wider EU.

The plan underscores the critical interplay between technological and social innovation as dual drivers of the clean digital energy transition required at EU and global levels. Extensive stakeholder engagement has highlighted the importance of leveraging existing foundations, fostering collaboration and knowledge sharing, upskilling the workforce, building public awareness, and establishing a clear strategic vision to enable the technological advancements necessary for this transition. Achieving this transformation will require significant investments in human, financial, and infrastructural resources to establish the competences and systems necessary for a resilient and sustainable energy future.

The fundamental changes required across the energy system include modernising infrastructure to ensure it is fit for a digital and decentralised future, optimised to maximise capacity and performance, and capable of integrating an increasing amount of variable energy sources. The future energy system must facilitate communication and integration between smart, distributed assets, integration of cutting edge technology and optimisation of energy data usage to effectively plan and manage the system, whilst doing so in a secure and consumer-driven manner. Nations must acknowledge the social context within which this transition is occurring, and ensure social and commercial innovations are prioritised, be it through empowerment of new market stakeholders (e.g. innovators, prosumers, energy communities etc.), support for new business models, and regulatory frameworks fit for a new energy system. This transition will necessitate expertise and contributions from all sectors of the quadruple helix—academia, industry, government, and civil society—and collaboration across all EU Member States.

Building on the alignment of national priorities and the expertise of engaged stakeholders, this plan identifies seven priority opportunity areas to drive the digital clean energy transition. The WEnnovate consortium will seek relevant funding, implementation pathways, and new collaboration opportunities to advance these initiatives:

1. Designing for new energy systems: observability, standardisation and interoperability
2. Designing for new energy systems: Grid usage and management (capacity, aggregation, flexibility & ancillary Services)
3. Facilitating international knowledge exchange for energy sharing groups (communities and hubs)
4. Best Available Technologies (BAT) Open Repository: Curating resources for the digital energy transition.

5. Advancing digital energy innovation education: Tailored training for leadership and workforce development.
6. Strengthening communication and dissemination networks for the digital energy transition
7. Fostering energy innovation ecosystems for the digital energy transition

This Joint Programme Plan does not aim to provide an exhaustive roadmap for achieving the clean digital energy transition, given the expansive range of required actions and international collaborations. Instead, it identifies impactful, actionable opportunities that will make a meaningful difference in the transition strategies of participating countries and stakeholder groups. By fostering collaboration, developing networks, and enabling ecosystem growth, the plan aims to support the EU's ambition for a resilient, secure, affordable, sustainable, innovative, and inclusive digital energy system.

Introduction

WEnnovate Background and Context

This document, D5.3 Joint Long-term Programme plan, has been prepared as part of the EU-funded WEnnovate project (Full title: *Connecting Minds, Powering Change.*; Ref #: 101134909).

The WEnnovate project addresses the ongoing transformation of the EU's energy system and the essential role that digitalisation must play within this (both requirement and added benefit)[1]. The digital energy transition is driven by the need to decarbonise our energy systems, and modernise our infrastructure to be fit for the digital age, supporting sustainability, security and global competitiveness[2].

The energy system itself is facing fundamental changes, with breakthrough technological and social innovations and evolving sector demands rewriting the rules of the system and demanding a more connected, intelligent, efficient, reliable and sustainable system[3].

Technology and digitalisation is key to facilitating the decarbonisation of the system, via integration of renewable energy sources, and optimisation of energy flows. This includes big data, artificial intelligence, the internet of things, modernised sensors and smart grid technologies, 5G and 6G communication networks and many more[4]. Collectively, these technologies, existing and emerging, deep tech and digital, can support the changes to the system, optimising performance and stability, adding capacity, storage and flexibility to adapt to multidirectional flows of distributed, decentralised energy assets, from EVs to variable RES generators. They can support prediction of energy consumption,

[1] European Commission. (2024a). Digitalisation of the energy system. Energy.ec.europa.eu. https://energy.ec.europa.eu/topics/energy-systems-integration/digitalisation-energy-system_en

[2] GOV UK (2021). Digitalising our energy system for net zero Strategy and Action Plan 2021, https://assets.publishing.service.gov.uk/media/60f5d393d3bf7f568dc8a58b/energy-digitalisation-strategy.pdf.

[3] Ofgem (2017). Upgrading Our Energy System. https://www.ofgem.gov.uk/sites/default/files/docs/2017/07/upgrading_our_energy_system_-_smart_systems_and_flexibility_plan.pdf.

[4] European Commission. (2024b). Digitalisation of the European Energy System | Shaping Europe's digital future. Digital-Strategy.ec.europa.eu. https://digital-strategy.ec.europa.eu/en/policies/digitalisation-energy

optimised management of power plants, inform strategic planning, and improve data access and transition. In short, digitalisation is the key to revolutionising our energy system for the future[5] [6].

The digital energy landscape is further being redrawn not only at a technological level, but also social and economic, with business models being reimagined, and society taking a more proactive role within the space - democratisation and empowerment of new energy stakeholders (i.e. prosumers, energy communities and sharing groups etc.) are being propelled by proliferation and easy access to distributed and decentralised energy assets and devices (i.e. Internet of Things (IOT)), with improvement in connectivity, storage, and security (blockchain)[7].

Despite these advancements, challenges persist - including technical, economic, legislative, and societal barriers - which the EU aims to address through strategic coordination and funding[8]. Through landmark initiatives and strategies (European Green Deal, A Europe fit for the Digital Age, REPowerEU, "Digitalising the Energy System—EU Action Plan", New European Innovation Agenda (NIEA) etc.) the EU is taking steps to to combat climate change, enhance energy security, and reduce dependence on fossil fuels, particularly from Russia, all the while navigating the complexities of this digital energy transition, fostering collaboration across policy, finance, and innovation sectors, and prioritising privacy, (cyber)security and consumer protection and safety for a secure and inclusive energy transition.

Central to the EU's strategy to address these challenges and opportunities is a comprehensive restructuring of the energy system based on three key pillars: reducing overall energy consumption, expanding electrification across various sectors, and implementing renewable and low-carbon fuels where electrification is not feasible[9]. By 2030, the EU aims to reduce greenhouse gas emissions by 55% and increase the share of renewable energy to 45%, expanding wind and solar power generation

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[5] Danieli, M. (2024). Navigating the energy transition: Unlocking grid flexibility through digital technologies, https://www.google.com/url?q=https://www.hitachienergy.com/uk-ie/en/news-and-events/blogs/2024/05/unlocking-grid-flexibility-through-digital&sa=D&source=docs&ust=1732817841580954&usg=AOvVaw0uO1vmzKeBGavMmKmB6YLI

[6] Ahmad, T., Zhu, H., Zhang, D., Tariq, R., Bassam, A., Ullah, F., AlGhamdi, A. S., & Alshamrani, S. S. (2022). Energetics Systems and artificial intelligence: Applications of industry 4.0. Energy Reports, 8, 334–361. https://doi.org/10.1016/j.egyr.2021.11.256

[7] Szulecki, K., & Overland, I. (2020). Energy democracy as a process, an outcome and a goal: A conceptual review. Energy Research & Social Science, 69, 101768. https://doi.org/10.1016/j.erss.2020.101768

[8] European Commission, Directorate-General for Energy, Lise, W., Ansarin, M., De Haas, V., Bene, C., et al., Study on promoting energy system integration through the increased role of renewable electricity, decentralised assets and hydrogen : final report, Publications Office of the European Union, 2024, https://data.europa.eu/doi/10.2833/560304

[9] European Commission. (2024d). EU strategy on energy system integration. Energy.ec.europa.eu. https://energy.ec.europa.eu/topics/energy-systems-integration/eu-strategy-energy-system-integration_en

capacity from 400 GW in 2022 to at least 1,000 GW[10]. This agenda includes modernising energy infrastructure through the development of smart grids to enhance efficiency, reliability, and security, and fostering a decentralised energy mix to increase resilience and reduce reliance on centralised fossil fuel sources[11].

The WEnnovate project sits at this inflection point and aims to bring together key stakeholders and insights to build the necessary collaborations required for an innovation driven, local, socially inclusive, clean energy transition.

Purpose and objectives of the Joint Programme

This Joint Programme action plan is designed to accelerate this digitalization of the energy system through collaborative efforts among stakeholders in four participating EU countries: Slovakia, the Netherlands, Hungary, and Ukraine, whilst also securing alignment with leading EU bodies (DG ENER) and other international stakeholders with a shared commitment to driving the transition.

This plan specifically targets common challenges and actions prioritised for their collaborative potential, between the core WEnnovate partner member states.

This Joint Programme action plan will be used as a basis for identifying and applying for future funding, and identifying new collaboration partners, for the actions documented within. Whilst the actions have been curated to work together as part of a holistic plan, each can also be addressed individually according to funding and stakeholder requirements at the time.

Long-term success for the WEnnovate project and for this Joint Programme action plan will be based upon the implementation of actions within this plan in the short-to-medium term (years 1-3), as well as the broader collaborations it has enabled, and will continue to generate (years 4+).

Whilst preliminary resource requirements (budget and timelines) and activity allocation (stakeholders interested and profile required) has been considered as part of the outreach and co-creation activities of the WEnnovate project, validation of stakeholders and appropriate funding opportunities is ongoing and therefore we expect these details to evolve up to the point of formal application for future funding public and private funding opportunities based on the requirements of that call, and the capacities of

[10] European Commission. (2023b). Renewable Energy Targets. Energy.ec.europa.eu. https://energy.ec.europa.eu/topics/renewable-energy/renewable-energy-directive-targets-and-rules/renewable-energy-targets_en

[11] European Commission (2024). In focus: EU investing in energy infrastructure. https://energy.ec.europa.eu/news/focus-eu-investing-energy-infrastructure-2024-10-15_en.

interested partners at the time of said application. Having said this, initial estimates on budgets and timeframes are included within the actions and partner capacity identification is ongoing.

Defining the scope (alignment with EU Policies and Strategies)

As outlined above, the WEnnovate Joint Programme action plan sits within the context of a series of EU and national documents and strategies that aim to support the digital energy transition. Despite this abundance of strategies and plans, there is a lack of coherence both at an EU-to-National and National-to-Regional level amongst all partner nations involved within WEnnovate (and beyond).

The WEnnovate has focused on the EU's core strategies in this space, namely the "Digitalising the Energy System—EU Action Plan" (Fig 1) produced by DG ENER as a hallmark for designing and coordinating the actions within this document and the set of 4 National Action Plans also produced within the project.

WEnnovate's Joint Programme action plan is specifically targeted at actions that are best suited to international collaboration between partners across the WEnnovate regions and the wider EU. The plan aims to define practical and actionable project ideas that can drive forward the broader ambitions outlined in the core EU strategies and support international and national alignment to this end.

Fig. 1: Priorities from "Digitalising the Energy System—EU Action Plan"

European ambitions for the digital energy transition

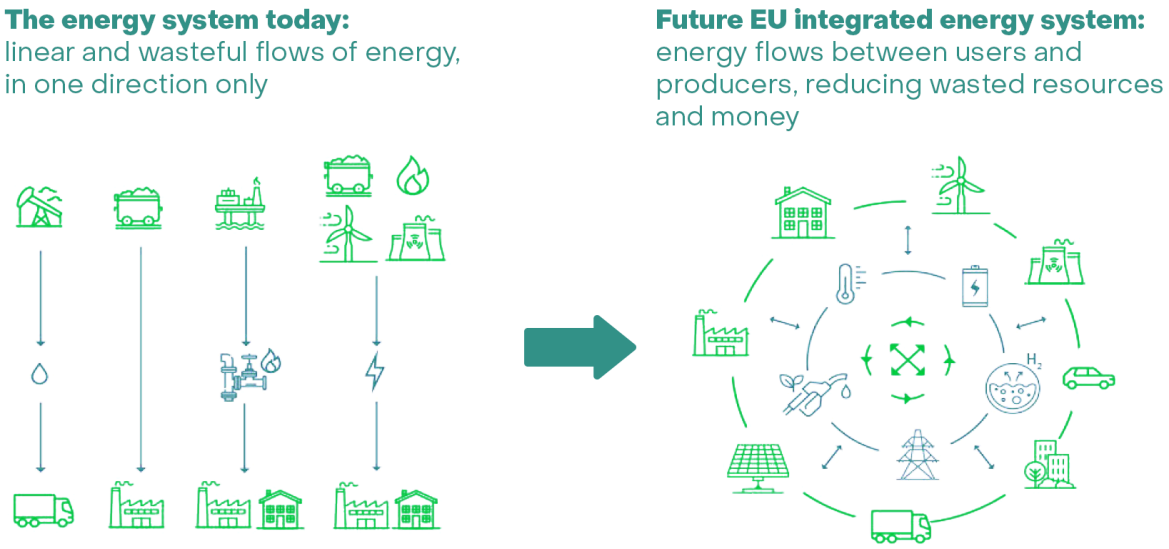

Fig.2 Transition to Future EU integrated energy system

The European Union has embarked on an ambitious plan to digitise its energy system, aiming to transform the region into a smarter, more interactive, and sustainable energy environment. This plan forms part of the broader European Green Deal and REPowerEU initiatives, which seek to address climate change, enhance energy security, and reduce dependency on fossil fuels, particularly from Russia. To navigate the complexities of this digital transition, the EU published the Digitalising the Energy System - EU Action Plan (COM/2022/552). This action plan outlines specific steps for integrating digital technologies into the energy sector, ensuring that the transition is both efficient and secure.

The EU's strategy for comprehensive decarbonization of its economy necessitates a fundamental restructuring of the energy system. This transformation hinges on three key pillars: reducing overall energy consumption, expanding electrification across various sectors, and implementing renewable and low-carbon fuel alternatives where electrification is not feasible. The integration of these systems is crucial for achieving cost-effective decarbonization while maintaining the necessary flexibility in the energy grid[12].

[12] European Commission, Directorate-General for Energy, Lise, W., Ansarin, M., De Haas, V., Bene, C., et al., Study on promoting energy system integration through the increased role of renewable electricity, decentralised assets and hydrogen : final report, Publications Office of the European Union, 2024, https://data.europa.eu/doi/10.2833/560304

To meet these ambitious goals, the EU has introduced a series of policy measures and directives. These include revisions to existing frameworks such as the Renewable Energy Directive (REDIII), the Energy Performance of Buildings Directive (EPBD), and the Energy Efficiency Directive (EED). New regulations like the Alternative Fuels Infrastructure Regulation (AFIR) have also been implemented. Recent additions such as the Wind Power Package and the Grid Package further support these objectives.

Key targets for 2030 and beyond

By 2030, the EU aims to reduce greenhouse gas emissions by 55%, increase the share of renewable energy to 45%, and significantly expand its renewable energy capacity. The EU's strategy includes increasing wind and solar power generation capacity from 400 GW in 2022 to at least 1,000 GW by 2030. Additionally, the region is set to deploy over 320 GW of solar-photovoltaic capacity by 2025 and nearly 600 GW by the decade's end. Offshore renewable energy will also grow, with plans to reach 317 GW[13].

To accommodate this increase in renewable energy, the EU plans to modernise its energy infrastructure. This includes the development of smart grids, which will enhance efficiency, reliability, and security, while supporting the integration of variable renewable power into electricity networks. Notably, the modernization will focus on creating a decentralised energy mix, making the system more resilient and less reliant on centralised fossil fuel sources.

The transition to a decarbonized energy system requires a multifaceted approach. This includes accelerating flexibility measures to match the pace of renewable energy deployment, ensuring that both supply and demand can adapt to changing conditions. It also calls for deeper integration between different sectors, increased consumer engagement, better utilisation of assets for demand-side flexibility and adequacy services, enhanced energy trading across all markets, and the development of a more innovative and enabling regulatory framework. Successfully integrating this flexibility into the system will allow for significantly increased competitiveness of the EU on a global scale, with the economy built on the foundations of a more agile, scalable energy system.

Net Zero by 2050 and cross-sectoral electrification

In pursuit of the EU's 'Net Zero by 2050' goal, substantial investments are required to connect the energy sector with other industries such as mobility, buildings, and agriculture. Electrification will be pivotal in lowering emissions across these sectors. However, the annual gap in infrastructure investment, estimated at over €406 billion, presents a significant hurdle. Bridging this pitfall is critical to enabling green transition initiatives, including cross-sector applications like bidirectional EV charging.

[13] European Commission. (2024c). Digitalisation of the European Energy System | Shaping Europe's digital future. Digital-Strategy.ec.europa.eu.
https://digital-strategy.ec.europa.eu/en/policies/digitalisation-energy

The EU Energy System Integration (ESI) Strategy, published in July 2020, outlines 42 key actions across six pillars to address these challenges. As of October 2023, the majority of these actions have been implemented or are on track, demonstrating the EU's commitment to its energy transition goals.

The role of digital technologies

Digitalization is critical to achieving these goals. The European Commission is promoting the use of advanced technologies such as the Internet of Things (IoT), smart metres, 5G and 6G networks, cloud-edge computing, and digital twins of the electricity system. These technologies will optimise energy consumption, enhance grid management, and support the integration of renewable energy. They also necessitate due care and considerations for requirements on cybersecurity, consumer data and privacy, interoperability and much more.

A key pillar of this effort is the creation of a pan-European energy data space, which will facilitate data sharing among stakeholders. This data infrastructure is expected to drive innovation in energy services and improve market participation. The Commission aims to have this data space operational by 2024.

Additionally, smart IoT devices, already installed in over 51% of EU households, will play a crucial role in empowering consumers. The digitalization of energy consumption will give consumers greater control over their energy use, reduce costs, and contribute to a more efficient energy market[14].

Despite these advancements, several challenges persist in the digitalisation of the system and the integration of decentralised renewables. These barriers can be categorised into four main areas:

1. Technical challenges: These include insufficient expansion and reinforcement of distribution networks, delays in smart metre deployment, inadequate digitalization at the distribution level, and prolonged grid connection and permitting processes.
2. Economic and financial hurdles: High upfront costs for equipment and installation, as well as ongoing operational expenses, pose significant barriers to adoption.
3. Legislative and regulatory issues: The need to adjust regulations at the national level to align with EU directives and goals presents a complex challenge.
4. Societal factors: A lack of professional experience and skills in the renewable energy sector, coupled with limited consumer awareness and knowledge, hinders widespread adoption.

The Digital Spine and cross-sectoral connections

The concept of a Digital Spine has been introduced to help close the investment gap by utilising advanced digital technologies. By facilitating decentralised intelligence between sectors, the Digital Spine improves the sustainability and efficiency of current infrastructures. This approach helps optimise renewable energy usage across various sectors, thereby reducing the need for massive investments in physical infrastructure.

[14] European Commission (2022). Digitalising the energy system - EU action plan. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52022DC0552&qid=1666369684560.

The Digital Spine also seeks to enhance communication and standardisation across digital infrastructures, particularly where different sectors intersect. By simplifying the deployment of renewable energy and enhancing energy flexibility, this strategy aims to advance sustainability goals while ensuring Europe's long-term economic competitiveness.

Investments and infrastructure

To meet its ambitious targets, the EU estimates that €584 billion will be required for investments in the electricity grid by 2030, with a significant focus on digitalization. This includes building the necessary infrastructure to support the deployment of 10 million heat pumps and 30 million zero-emission vehicles by 2030[15].

A large portion of these investments will be channelled into smart grid technologies, which are vital for coordinating between transmission and distribution operators. Smart grid indicators will help guide these investments, ensuring that the grids can handle the new demands of a decentralised energy system.

To address these challenges and support the energy transition, the EU has implemented or proposed a wide array of policies, regulations, and initiatives. These include the Carbon Border Adjustment Mechanisms (CBAM), FuelEU Maritime Regulation, Gas and Hydrogen market decarbonization package, reforms to the EU electricity market design, and the proposed Net Zero Industry Act. Additionally, strategies such as the Renovation Wave, EU Hydrogen Strategy, and the upcoming EU Heat Pump Action Plan aim to tackle specific aspects of the energy transition.

Cybersecurity and consumer protection

As the energy system becomes more digital, the EU is placing a strong emphasis on cybersecurity. New rules are being introduced to protect the electricity and gas networks from physical, cyber, and hybrid attacks. The NIS2 Directive will be key to safeguarding energy infrastructure, while additional measures will ensure resilience against potential threats.

Consumer empowerment is also a priority, particularly for vulnerable populations. The digitalization of the energy system will provide consumers with better access to energy services, helping to protect them from price volatility and energy poverty.

Reducing energy use in the ICT sector

The EU recognizes that the Information and Communication Technology (ICT) sector's growing energy consumption poses a challenge to its climate goals. By 2030, the ICT sector could account for up to 13% of global energy use. To address this, the Commission is extending Ecodesign rules and developing

[15] European Commission. (2022). Press corner. European Commission - European Commission. https://ec.europa.eu/commission/presscorner/detail/en/QANDA_22_6229.

energy efficiency standards for ICT products like data centres and computers. The new measures will also monitor energy use and carbon emissions from cloud computing and telecom networks.

Strategic coordination and funding

To ensure the success of its digital energy transition, the European Commission is fostering collaboration across policy, finance, and innovation sectors. Public-private partnerships will drive large-scale projects, and the Commission will create a Smart Energy Expert Group to guide the implementation of key initiatives. Strategic coordination will be supported by funding opportunities from programs like Horizon Europe, the Digital Europe Programme, and the LIFE Clean Energy Transition.

Financial support mechanisms play a crucial role in this transition. The European Hydrogen Bank, Clean Hydrogen Partnership, and various EU financing mechanisms for the energy sector have been established to facilitate investments and drive innovation in clean energy technologies. The success of the EU's energy transition relies on the coordinated implementation of these policies and initiatives, coupled with ongoing technological advancements and societal engagement. As the transition progresses, continuous monitoring and adjustment of strategies will be essential to overcome barriers and achieve the ambitious climate and energy goals set by the European Union.

Ukraine's ambitions for the digital energy transition are closely aligned with those of the European Union, particularly in the context of post-war recovery and integration into European energy markets. Following the disruptions caused by the ongoing conflict, Ukraine has recognized the necessity of modernising its energy infrastructure to enhance resilience and sustainability. This includes adopting digital technologies that facilitate the integration of renewable energy sources and improve overall energy efficiency. Ukraine aims to leverage advanced digital solutions such as smart grids, IoT devices, and data analytics to optimise energy consumption and management across its grid. By aligning its digital energy strategies with EU initiatives, Ukraine not only seeks to secure energy independence but also to contribute to the EU's broader goals of reducing greenhouse gas emissions and increasing renewable energy capacity. Collaborative efforts, such as participation in EU-funded projects and adherence to European regulatory frameworks, will be essential for Ukraine to effectively transition towards a decarbonized and digitally-enabled energy system, fostering both national growth and regional stability[16] [17] [18].

[16] Digitalisation: An enabler for the clean energy transition. (n.d.). https://www.epc.eu/content/PDF/2023/Vodafone_DP_FINAL.pdf

[17] Ionan, V. (2024, October 18). Ukraine sets example for EU on digital integration. The Parliament Magazine. https://www.theparliamentmagazine.eu/news/article/oped-ukraine-leads-the-way-on-digital-integration-with-the-eu

[18] Union of Entrepreneurs and Employers. (2024). Position paper on Ukraine digital policy. Retrieved from https://ppl-ai-file-upload.s3.amazonaws.com/web/direct-files/35342964/d815fb03-6144-4e60-aa56-41cfee228384/Position-paper-on-Ukraine-Digital-Policy.pdf

Methodology and Development Process

The WEnnovate project has used a combination of models and processes throughout the project lifecycle. Our initial framing on how to approach a transition built on the Dutch DRIFT model (Fig. 3), whilst our approach to the needs and core focus areas for the digitalisation and decarbonisation of the energy sector built on and adapted DG ENER's framework for Digitalising the Energy System as above (Fig. 1).

Transition model: The WEnnovate project approached the challenge of addressing the digital energy transition through the lens of the X-curve framework (WEnnovate interpretation in Fig 3.), as developed by The Dutch Research Institute For Transitions. Rotterdam, The Netherlands[19]. The model emphasises the importance of a participatory process to ensure justice and sustainability, and the role of not just technology, but also social innovation within a transition, an essential pillar of WEnnovate's approach.

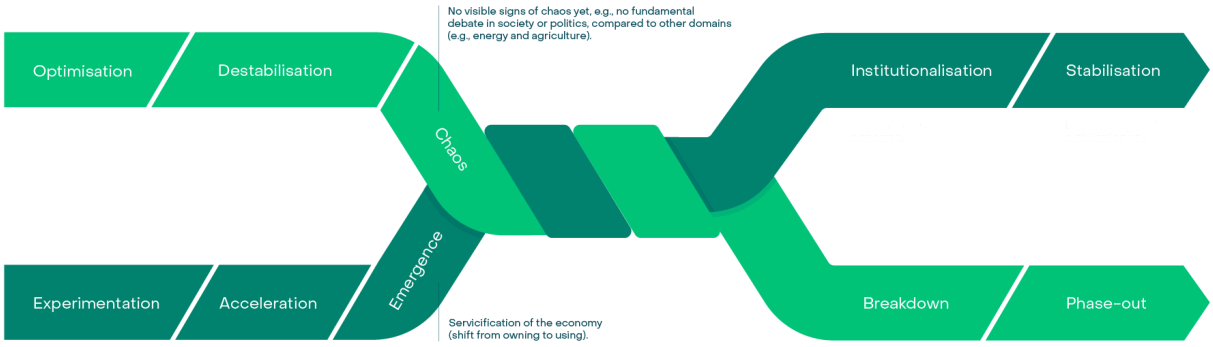

Fig. 3 - WEnnovate's adaptation of the X-framework developed by DRIFT

Within the model's "X-curve", the energy system is currently at the "chaos" state, an inflection point on the verge of systematic breakdown and rebuilding, with old and new systems coming to a head. Incumbent players are able to thrive within an regulatory and social ecosystem that still supports the old system (i.e. tariff models and market subsidies that dissuade innovation or change from the centralised energy model) whilst local governments, end-users and new players are calling for new legislation and support that favour the incoming decentralised system (i.e. energy sharing and flexible grid connectivity). This is a picture reflected across the EU, with all Member States, regardless of their degree of transition maturity, experiencing significant differences in transition ambitions (scale and speed) between sector stakeholders. Particularly within the WEnnovate partner countries, whilst a

[19] drift. (2024, February 24). Transitions • DRIFT. DRIFT. https://drift.eur.nl/en/about-drift/transitions/

growing force, those in favour of a rapid transition in line with the EU's ambitions remain a relatively limited community.

Energy Digitalisation model: Building on this transition model approach and incorporating key elements from DG ENER's action plan (Fig. 1), WEnnovate designed and implemented its own model fit the project's ambitions and stakeholder engagement approach (Fig. 4) - incorporating the project's initial research and stakeholder inputs, and placing a key focus on practical, action driven categorisation.

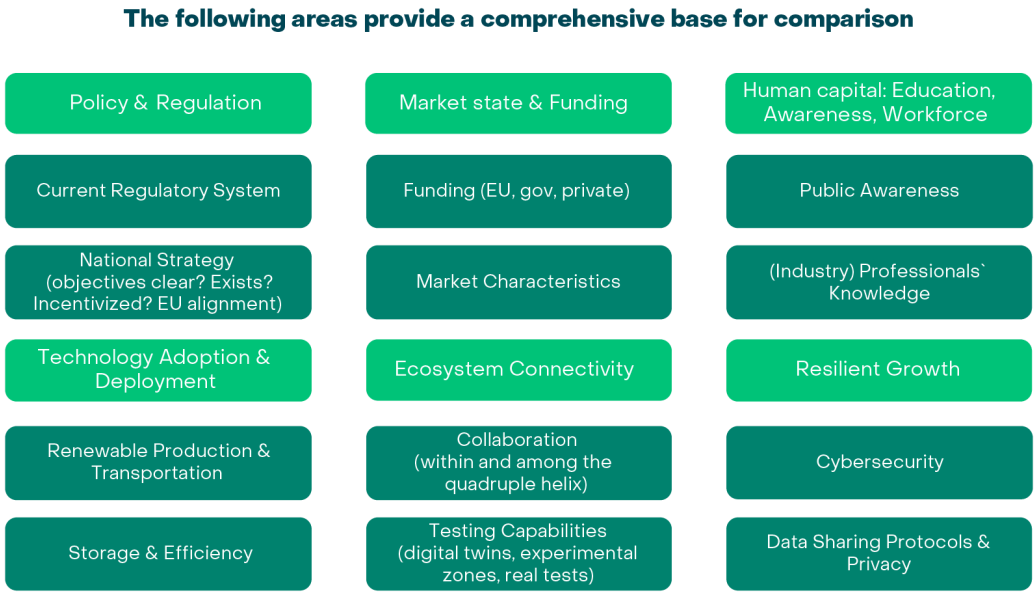

Fig. 4: WEnnovate's framework for the digital energy transition

Action co-creation: The actions themselves are the result of a series of desktop analysis, in-depth interviews, online surveys, and multi stakeholder workshops and ongoing engagement that cut across the quadruple helix. The WEnnovate project outputs are the result of broad stakeholder engagement across the partner regions and wider EU stakeholders, with a total of 408 stakeholders engaged throughout the dialogue and co-creation process, and 32 multi-stakeholder co-creation and planning meetings complementing the direct engagement with ecosystem representatives.

Investigation was begun at a national level, building the foundations for the National Action Plans, with subsequent alignment on cross-over topics and priorities between the National partners. The actions themselves have been cocreated with stakeholders across all partner ecosystems and aligned to the

priority areas identified within WEnnovate's research and stakeholder engagement phase. A key driver of the success of the WEnnovate project will be actionable outputs with owners / assigned stakeholders to drive these actions forward and therefore identification of the appropriate stakeholders has been and continues to be a priority.

The Joint Programme action plan is a collaborative document produced by the WEnnovate consortium with a primary focus on collaborations between stakeholders from the consortium member nations (Slovakia, the Netherlands, Hungary and Ukraine) however all collaborations and target actions identified are open to broader stakeholder engagement and support from across the EU.

Driving towards an international action plan was an essential pillar of WEnnovate's work and the opportunity for shared learnings between Member States at different stages of their own national transformations was a recurring theme within the stakeholder engagement. The vast majority of technological and social challenges that will unlock the transition have common roots, regardless of national borders, particularly within the context of the EU's ambition for a Single Market and joint responsibility in the face of the existential threat of climate change, and therefore working together is essential to achieve our global ambitions.

Given the complexity and cross-cutting nature of the digital energy transition and its impact on virtually all corners of our society and economy, a diverse, representative stakeholder view was essential for ensuring solutions are inclusive and widely adopted.

- **Academia:** Universities and research institutions contributing expertise and innovation.
- **Industry:** Energy companies, technology providers, and startups driving implementation.
- **Government:** National and regional authorities facilitating policy and regulatory support.
- **Civil Society:** Consumers and community organisations ensuring societal needs are met.

WEnnovate also placed a key focus on inclusion of under-represented stakeholders within the energy transition, ranging from new market entrants to female energy sector leaders.

Structure of the Joint Programme Plan Document

This Joint Programme action plan will briefly present the key areas of strategic overlap and prioritisation (challenges and opportunities, shared infrastructure, etc.) across the participating Member States.

The Plan then outlines a list of prioritised actions, each formatted as an individual action card. Each of these is able to represent a standalone action / project for future funding however they have also been

curated to create synergies between one another and therefore the ultimate ambition of the Joint Programme action plan is for these to be addressed as a holistic unit.

It should be noted that a key challenge across the ecosystems was securing definite commitments to the targeted actions due to a number of restrictions (capacity, funding, etc.) and that the consortium partners are in ongoing conversation with several partners across each ecosystem regarding future collaborations. Reflecting this differing level of maturity in action readiness and consortium building, a number of fields within the action cards will require further refinement.

The Joint programme action plan is designed to be a living document and will be maintained and monitored by the partners within the WEnnovate project even following project completion to enable the implementation of target actions outlined. This is outlined within the Monitoring and Evaluation Section.

Overlap analysis

WEnnovate has conducted extensive analysis of the transition challenges and opportunities, as well as digital energy ecosystem maturity, at a national level for each Partner country represented within the WEnnovate consortium - this analysis is presented within the respective National Action Plans (D5.2). Within the Joint Programme action plan, we will primarily focus on the overlap analysis across these national contexts given the focus on collaboration potential and synergies.

The overlap analysis follows the structure used throughout WEnnovate's research to date (Fig. 4 Framework for the digital energy transition). As part of the WEnnovate Deliverable "D.3.2. Report of needs, problems and obstacles for deeptech development in participant-countries", an initial analysis revealed a key number of overlapping transversal challenges facing the four countries involved in the WEnnovate project. These primary challenges can be seen in Fig.5 below and are described in greater detail within this section. Each of these challenges is mapped against, and referenced in line with the WEnnovate digital energy transition framework (Fig. 4)

It is worth noting that given the energy transition will require a vast combination of different technological solutions, with no single technology able to achieve the required changes alone, these key overlap areas have been designed to be technology agnostic. Nonetheless, to support concrete and practical mitigations and related actions, several of the proposed actions have been aligned to a series of technological and social innovations prioritised across all partner countries.

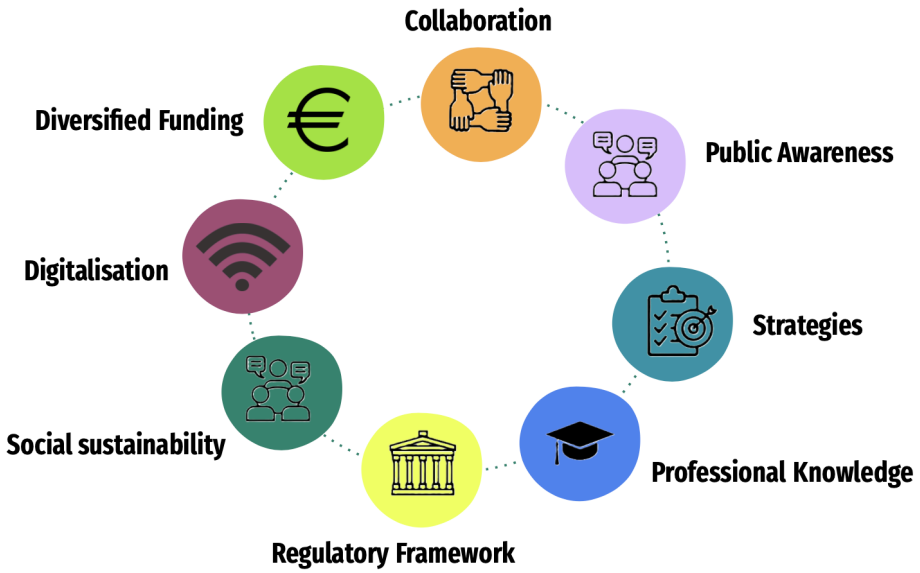

Fig.5 D3.2 analysis on overlapping challenges for the digital energy transition

Policy & Regulation

Policy & Regulation: Common challenges & needs

All partner countries are facing key challenges regarding national **strategies** & the accompanying legislative and **regulatory frameworks**.

A major challenge faced by all four partner countries is the difficulty in aligning on a coherent, **single vision** of the energy transition within their national strategies, leading to **fragmented** actions and a lack of strategic planning between both central and regional authorities and across industry. Whilst the Netherlands and Ukraine are demonstrating proactive progress in aligning with the EU's ambitions for the energy transition, the primary challenge is around knowledge of, and alignment to the EU's ambitions for the digitalisation of the sector (EU Action Plan for digitalisation of the Energy Sector). In the Netherlands, widespread support for the energy transition is in place however infrastructure and capacity challenges are stalling progress, with optimised, more efficient use, alongside necessary modernisation of infrastructure, essential to unlock progress, and both highly intertwined with the digital agenda. For Ukraine, the ongoing conflict has underlined the importance of energy security and independence, and the role that decentralised, digitally enabled energy systems have in driving this. For Hungary and Slovakia, both appear to be following a path of minimal compliance, with both recently being cited by the European Commission for failing to implement the Renewable Energy Sources (RES) Directive for the accelerated integration of RES into their national regulations (source). Although there is a notable difference in political will within this area, all 4 countries are nonetheless looking to increase the level of digitalisation and integration of renewables within their energy systems (in spite of differing speeds of change) and national strategies and leadership must be updated and aligned to reflect this.

This lack of strategic alignment is also reflected within the **regulatory framework**, where energy related laws are acting as a **barrier to implementation** of energy efficiency solutions, the roll-out of renewables solutions, and innovation and technological advances. In both Slovakia and Hungary, an extended 'stop' on new RES deployments severely hampered progress over the past decade, and despite this now having been overturned, barriers remain, notably a rigid and bureaucratic institutional framework which creates a lag in implementation of smart digital energy tech and RES. It should be noted for both countries key factors influencing this rate of change are their existing base of steady, low emissions nuclear energy, a lack of incumbent industrial and electorate pressure and low climate awareness and engagement. Whilst regulatory barriers and grid access challenges remain in both the Netherlands and Ukraine as well, the challenge is primarily around the speed at which EU energy regulations are being translated into national law, and the desire for a more progressive, flexible regulatory system that can support the desired transition.

See Action 1 in the Slovak National Action Plan, Action 3 in the Dutch National Action Plan, Action 1 in the Hungarian National Action Plan, and Actions 1 and 2 in the Ukrainian National Action Plan.

Policy & Regulation: Common opportunities and synergies

Although updates to national strategies and regulatory frameworks are consistently targeted by all participating countries, these have not been identified as prioritised collaboration areas for the Joint Programme given the highly politicised and unilateral nature of these activities.

Nonetheless, based on these challenges, all partners have identified **climate and digital energy system education** and **awareness building**, as well as **effective knowledge sharing** as key activities that have the potential to unlock and enable changes in this space. These opportunities include identifying clear strategies and successful mechanisms for digital energy system **advocacy** activities towards public authorities, as well as providing **guidance and best practice** to industry stakeholders on what they can be doing, how, and to what benefit, regarding implementation of technological and social changes for the transition. For Hungary and Slovakia, there is also a major challenge in altering **public discourse** and driving broader climate education as a means of exerting political pressure on public authorities to accelerate change.

WEnnovate has identified numerous opportunities for synergies across these educational, knowledge sharing and best practice areas, which are discussed in more detail within the Human Capital section.

As such, whilst there are no specific joint actions targeting the policy and regulation directly, we do see significant potential for the other actions outlined within this plan to influence and drive required changes in this field, namely driving national strategy alignment, and facilitating a more appropriate and adaptable regulatory system for the rollout of the RES and digital technologies and innovations needed for the transition.

Market State & funding

Market State & funding: Common challenges & needs

All four partner countries face major challenges in the **modernisation** of their current **energy infrastructure** and the availability of national funding to modernise it, and integrate RES.

In Hungary and Slovakia, the deployment of renewable energy sources (RES) has been significantly hindered by **government interventions in energy pricing**. National policies promoting low-cost, government-subsidized energy have reduced consumer and industrial incentives to adopt RES and slowed digital innovation within the sector, particularly at the roll out of digital / smart solutions at a

residential and consumer level, fostering complacency with the status quo. Additionally, both countries maintain tariff systems—such as Slovakia's G-Component, which imposes fees on connecting new electricity sources to distribution networks—that disproportionately disadvantage green projects and create barriers to entry for small and medium-sized enterprises (SMEs).

In the Netherlands, although the market has more readily embraced the transition and investment is being made targeted at the energy system, work remains to ensure this support actually reaches smaller market players and not just market incumbents, thereby facilitating the market's innovation potential. Additionally the Netherlands also faces its own tariff challenges with a system currently structured around a centralised energy sector.

For Ukraine, the ongoing conflict has forced a rapid acceleration in the transition of its energy system, moving from a hyper-centralised, monopolised energy sector, to one which is looking to rebuild following decentralised, digital and green ideals. With funding challenges in place prior to the conflict, this has been exacerbated, and finding the resources to drive the required changes and rebuild damaged infrastructure is a significant challenge.

Across all partner countries, significant challenges hinder the adoption of digital innovations and the entry of **new market players**. These challenges stem from the dominance of large corporations and established industry leaders, which tend to be more risk-averse and conservative compared to agile startups. These legacy players are often the primary beneficiaries of existing subsidy programs, further disadvantaging SMEs and startups that typically have greater innovation potential.

Similarly, **limited accessibility to national funding** for energy system innovation—both in terms of availability and ease of access—presents a significant barrier, particularly for international collaborative projects. Heavy reliance on European funding, combined with bureaucratic inefficiencies and cumbersome national funding processes, further contributes to the underutilization of available resources.

Market State & funding: Common opportunities and synergies

To improve innovation in the energy ecosystem and ultimately lead towards a more resilient, diversified and balanced energy mix, a **diverse array of funding** instruments and sources is essential. The complexity and scale of the transition demand financial solutions tailored to various stages of innovation, from R&D to commercialization. This funding must balance both support for high-risk, long-term projects typical of energy innovation and often overlooked, as well as creating opportunities to pilot existing technologies within their own national context, to accelerate deployment of functional,

proven digital energy solutions. By offering a mix of grants, loans, subsidies, and private investments, alongside improved support for accessing EU funds and fostering public-private partnerships, we can better incentivize and accelerate the development and deployment of the technologies required for the transition.

Whilst there are **no specific joint actions** defined in the plan that directly correlate to the areas of market state and funding, again largely due to these being driven by national politics, it can be noted that actions such as digital energy upskilling, and enhanced communication and dissemination on digital energy opportunities should lead to better engagement and success with existing funding opportunities and create new opportunities for the uptake of RES and digital solutions.

See Action 1 in the Slovak National Action Plan, Action 5 and 7 in the Dutch National Action Plan, Action 1 and 3 in the Hungarian National Action Plan, and Actions 3-10 in the Ukrainian National Action Plan.

Human Capital

Human Capital: Common challenges & needs

All partners identified a range of human capital challenges across their ecosystems, primarily stemming from a **lack of professional expertise**—both within industry and public authorities—and **low public awareness** of the benefits associated with the digital energy transition.

On the professional front, while all participating nations possess high levels of expertise in key areas central to the energy transition, there is a widespread gap in understanding the opportunities, applications, and benefits of digital and renewable energy technologies. This gap is evident across the spectrum, from SMEs to large incumbents, and undermines effective planning and motivation to drive the transition forward. Although all partner nations address digital and energy skills in their key strategies, a lack of strategic coordination has hindered the effective implementation of workforce skill development programs, particularly in relation to the role of digital technologies.

Similarly, public awareness remains critically low in several countries, particularly Slovakia, Hungary, and Ukraine. In the Netherlands, awareness gaps also persist, particularly concerning the integration of digitalization and renewable energy sources (RES) to enhance energy security, efficiency, cost savings, and environmental impact. This lack of public understanding contributes to a societal acceptance of the status quo, reducing the pressure on public authorities and industry to prioritize and implement transformational change.

Human Capital: Common opportunities and synergies

Recognizing the critical importance of a skilled workforce and an informed population for advancing the digital and energy transitions, human capital considerations are embedded across **all actions** within the Joint Programme. While numerous educational materials and networks already exist to support these goals, their effectiveness is often limited by challenges in dissemination and accessibility.

WEnnovate has identified a significant opportunity to **enhance the reach and impact of these resources** through targeted communication and dissemination strategies tailored to specific sectors. This approach aims to improve knowledge flow within the ecosystem while also strengthening foundational expertise through the development of **shared, open-access, and modular educational materials** aligned with WEnnovate's priority challenge areas.

Within the consortium and its broader network, existing frameworks for developing upskilling materials, particularly in the digital domain, can be readily adapted to meet the unique needs of the energy sector. Beyond the creation and distribution of educational content, the Joint Programme presents a valuable opportunity for collaborators to engage in continuous shared learning about effective communication and dissemination practices. This includes strategies for fostering engagement and advocacy among public authorities, whose decisions significantly influence the trajectory of the energy transition.

See mainly Actions 3-6 in the Joint Programme, Action 2-4 in the Slovak National Action Plan, Action 3 in the Dutch National Action Plan, Actions 2 and 4-6 in the Hungarian National Action Plan, and Actions 11-16 in the Ukrainian National Action Plan.

Technology Adoption & Deployment

Technology Adoption & Deployment: Common challenges & needs

Similarly to human capital, technology adoption and deployment sits at the core of all the digital energy transition efforts of all partner countries, with extensive **digitalisation** (and a robust digital infrastructure) crucial for a sustainable and resilient energy transition. The shift towards more decentralised, renewable energy sources triggers increased complexity in managing energy production, distribution, and consumption as well as requiring better capacity management. Digital technologies offer tools to manage this - optimising energy flows, via real-time monitoring, predictive

analytics, and smart grid management, and integrating diverse distributed and emerging energy sources and devices (e.g., EVs and storage systems) that can help to maintain grid stability if properly leveraged.

Despite this, a key challenge experienced across all partners in this area is reinforcing the understanding that the energy transition and the digital transition cannot be seen as separate activities, and instead are integral to one another. Penetration of smart digital devices (i.e., smart metres) in Slovakia, Hungary and Ukraine remains relatively low whilst all countries face significant challenges in the balancing of their grid capacities given the influx and desired integration of new sources of RES. These challenges are further compounded by concerns around the increased complexity that digitalisation would introduce to already challenging energy systems, concerns around management, maintenance and failure of digital technology, conflicting information regarding needs and commercial upsides for digital technology roll-outs (e.g., cost-benefit analysis for smart metres in SK), and most importantly the risks around cyber security in such a strategically important sector, with universal reliance on the security of the national grid and internal access.

Beyond the acceptance challenge, there are also numerous areas of technological advancement that remain priorities for all partners, ranging from energy storage and flexibility solutions to balance supply and demand, and enabling stable energy flows; data collection and transparency (covering production, consumption, grid and distributed assets) to enable better decision-making and efficiency optimisation; communication and interoperability between energy hardware for seamless data sharing and system integration; and as previously mentioned, cybersecurity to enhance efficiency without compromising security.

Technology Adoption & Deployment: Common opportunities and synergies

Similarly to Human Capital considerations, **all actions** within the Joint Programme are intrinsically linked to the category of technology adoption and deployment. Notably there is significant interest in supporting the roll-out of existing technologies via improved accessibility of information of **best-available technologies**, with partners across the consortium and extended networks interested in supporting targeted knowledge sharing groups to advance key topics to facilitate this digitalisation. Within the Netherlands work has already begun regarding potential design principles for a more **standardised and interoperable** energy system which could guide future digital energy solution development and deployment, with a key opportunity to build on this work to identify common standards at a Single Market level. Similarly further collaboration has been targeted in the areas of local **energy groups and sharing, grid congestion and management,** and **cybersecurity** with proposed **knowledge exchange** forums and innovation activities such as **hackathons** identified as means to make collective progress and develop sector leadership and expertise in these areas.

See Actions 1-7 in the Joint Programme and Action 1 and 5-7 in the Slovak National Action Plan, Actions 1-12 in the Dutch National Action Plan, Action 1, 6-8, and 10-11 in the Hungarian National Action Plan, and Action 17-20 in the Ukrainian National Action Plan.

Ecosystem connectivity

Ecosystem connectivity: Common challenges & needs

Across all partner nations, significant challenges persist in fostering effective **stakeholder collaboration** and **knowledge exchange** across the quadruple helix. While many sectors maintain strong collaborative ties with specific parts of the helix, it is rare to see robust engagement across all components, despite the critical importance of such connectivity in developing holistic solutions. These solutions must not only address technological advancements but also consider social dimensions and the broader requirements of the energy transition, particularly in an increasingly complex landscape of stakeholders, from grid operators to prosumers.

This lack of comprehensive collaboration stems from a range of factors, including limited resources and networks to identify potential partners and disseminate opportunities effectively. Additionally, there is often a lack of sufficient incentives to encourage broader engagement, as well as misaligned mechanisms for market consultation, product development, and policy design. Addressing these barriers is essential to drive meaningful, cross-sector collaboration that can support a more inclusive and effective energy transition.

Ecosystem connectivity: Common opportunities and synergies

Extensive **collaboration** and effective **knowledge exchange**, particularly across the quadruple helix, also sit at the heart of **all actions** within this Joint Programme and can leverage existing forums, working groups and dissemination channels, supporting them to maximise impact. In and of itself, this Joint Programme will act as a driver for enabling future collaboration and the WEnnovate consortium members will work with their stakeholder network to identify future funding opportunities to realise these opportunities.

Resilient growth

Resilient growth: Common challenges & needs

Resilience within the digital energy transition encompasses both technological and social dimensions. On the technological side, key considerations include data sharing and access, as well as robust cybersecurity measures. On the social side, new models of engagement—such as inclusive energy participation, consumption, production, and sharing—are crucial for ensuring the transition's success.

The concept of social innovation within the energy sector remains underdeveloped. Most solutions are designed through economic and technological lenses, often overlooking critical social benefits and impacts. While partner countries actively support widespread energy access through extensive subsidization programs, these initiatives often fail to directly target vulnerable populations within the energy system. This oversight perpetuates energy inequalities and slows the evolution of the system, as market interventions frequently uphold the status quo without achieving meaningful reductions in disparities.

From a social perspective, emerging models of participation, such as energy communities and sharing groups, are gaining traction across partner countries. These models offer significant potential for social benefits, making it imperative to accelerate their adoption and address barriers to widespread implementation. Insights can be drawn from countries like the Netherlands, which have experienced an initial wave of deployment and can provide valuable lessons for other regions.

As previously mentioned, fostering consensus and confidence in cybersecurity and data-sharing approaches is critical not only to building trust and driving momentum behind the energy transition but also to ensuring its efficiency, effectiveness, and sustainability. Although these topics are being addressed across partner nations, their specific application within the energy system and integration into national energy strategies remain insufficiently developed. Addressing these gaps is essential for the transition's long-term success.

Resilient growth: Common opportunities and synergies

With broad experience of implementing energy groups and communities within the Netherlands, and early deployment of these models within Slovakia, Hungary and Ukraine, there is significant opportunity

for shared learning and collective upskilling on this topic, with notable interest also from third-parties in other EU countries. Education and awareness of the general public will be essential tools for encouraging the uptake of socially targeted initiatives and if well deployed will support access to, and create new opportunities for energy access and cost savings for those in or at risk of energy poverty.

With numerous models for centralised data gathering and sharing being deployed with WEnnovate countries (i.e. FEAK in Hungary, EDC in Slovakia, etc.), an objective assessment of what is and is not working well in the space will help progress expertise in this space and inform both standardisation, energy group, and grid congestion investigations, as well as supporting a transparent narrative to mitigate social concerns around energy data and privacy.

See Actions 1, 2, and 7 in the Joint Programme and Action 6-7 in the Slovak National Action Plan, Action 1-12 in the Dutch National Action Plan, Action 6, 8, and 10 in the Hungarian National Action Plan, and Action 22 in the Ukrainian National Action Plan.

Actions

Disclaimer on Stakeholder Inclusion

The inclusion of named stakeholders in this action plan serves as an expression of interest in future collaboration and is a direct result of the extensive stakeholder engagement process. It does not represent a binding commitment by any stakeholder to undertake or participate in the actions outlined, irrespective of funding outcomes. Stakeholder participation will be re-evaluated at the time of application for future funding opportunities, considering factors such as funding availability, specific call requirements, and the availability and capacity of consortium members. All engagements are subject to formal agreements to be established during the implementation phase. Beyond the stakeholders specified within the action descriptions, extensive outreach and discussion on action collaboration is ongoing and will be incorporated into future submissions.

Note on framework for categorising Actions

Although the framework outlined in Fig. 4 (WEnnovate's framework for the digital energy transition) has been used to drive stakeholder engagement and analysis throughout the WEnnovate project, a key learning in the latter stages of the project has been that assigning an action to a 'primary' framework category, i.e. human capital, or policy and regulation, acts as a barrier for engagement of a diverse stakeholder group. Even though an action may be relevant to a stakeholder, potential misalignment between the primary category and their field of primary expertise often dissuades involvement. As such whilst the WEnnovate digital energy transformation framework has been extremely useful throughout the process, it is not used as a primary framing tool within the Actions section of this Plan.

List of actions

1. Designing for new energy systems: observability, standardisation and interoperability
2. Designing for new energy systems: Grid usage and management (capacity, aggregation, flexibility & ancillary Services)
3. Facilitating international knowledge exchange for energy sharing groups (communities and hubs)
4. Best Available Technologies (BAT) Open Repository: Curating resources for the digital energy transition.
5. Advancing digital energy innovation education: Tailored training for leadership and workforce development.
6. Strengthening communication and dissemination networks for the digital energy transition
7. Fostering energy innovation ecosystems for the digital energy transition

1. Designing for new energy systems: observability, standardisation and interoperability

Action Title Designing for new energy systems: observability, standardisation and interoperability	**Action #**: JA1 **Action status:** Ideation

Action Objective:

- Iterate and advance design principles for digital energy ecosystems, particularly related to observability, standardisation and interoperability of digital devices within the energy system.
- Identify priority use-cases and define a reference architecture (i.e. energy groups / communities)
- Create specific protocols for observability, standardisation and interoperability of digital assets within digital energy ecosystems (i.e. energy groups / communities) ensuring consumer-friendly solutions are prioritised and alignment to existing market standards (e.g. S2).

Action Description:

This action is focused on designing energy systems fit for the digital age, able to meet the EU's climate ambitions, and apt for its aspirations for global competitiveness as a single market. This future energy system will result from increased asset digitization, decentralisation, and evolving consumer roles and business models.

In this new system, three concepts are key: observability (of the full technology stack of the energy system), standardisation (protocols and guidelines for consistent technology / process development) and interoperability (communication, data exchange, and compatibility of components). They will enable us to first, understand how the system operates, with high quality data, second, develop and evolve the system in a uniform, sustainable fashion, and thirdly scale and support increased integration and optimisation of new and existing digital, green energy assets.

This task requires strong governance, process and organisation given the scale of the task, and existing proliferation of efforts in this space across the EU. Engaging with existing efforts i.e. CENELEC, ETIP, EU Smart Energy working groups (Data4Energy) etc. will be key to drive effective collaboration and avoid siloed development for a challenge that impacts all corners of the EU and beyond.

Given the scale of the energy system, channelling efforts through specific use cases (e.g. designing for energy communities) will allow a more focused, and coherent development route, and support clear signposting and visibility for others within the ecosystem to drive improved collaboration and progress, ultimately delivering capacity, security and improved integration of renewables for the energy systems of the future.

- **Phase 1: Governance and ecosystem alignment**
  Establish key frameworks for collaboration, organisation, and decision making; create engagement strategy for existing ecosystem working groups and leaders in the space (e.g. ETIP, CENELEC, Data4Energy etc.) and drive specific engagement of national representatives within the EU working groups to ensure alignment.

- **Phase 2: International Dissemination and Consensus Building**
  Disseminate, test, and iterate the Club van Wageningen Design Principles for digital energy ecosystems with international partners. Aim to reach consensus on acceptable common denominators for shared principles. Consider requirements for a comprehensive array of digital energy assets (e.g. battery management system integrators) within the Internet of Energy. Consider market and regulatory factors across international ecosystems.

- **Phase 3**: **Development of Protocols and Reference Architectures**
  Build upon the agreed design principles to develop proposed protocols, standards, and reference architectures for system observability, interoperability, communication, and data exchange within the energy system. The initial focus will be framed within the context of energy communities and sharing hubs to facilitate local energy sharing and management.

- **Phase 4**: **Collaboration for Dissemination and Uptake**
  Collaborate with public authorities and industry groups to disseminate the proposed protocols and standards. Drive industry adoption through workshops, pilot projects, and inclusion in regulatory frameworks where appropriate.

Key Considerations:

- **Cross-Market Standardisation**: Leverage opportunities for standardisation across different markets to enable seamless integration and scalability of digital energy assets throughout the EU.

- **Data Security and Privacy**: Address data security and privacy concerns by ensuring that protocols comply with GDPR and other relevant regulations, incorporating robust cybersecurity measures.

Action Owner & supporting stakeholders (who)	**Timeframe (when)**
Confirmed interested parties: • SSF • In exploration with TwinTopics and TNO **Additional interested parties being validated across:** • Standardisation Bodies (e.g., CEN, CENELEC) • Industry Associations • Battery Management System Integrators • Digital Energy Asset Manufacturers • Energy Communities and Sharing Hubs • Technology Providers	Duration: 24 Months Phase 1 (Months 1-3): Establish governance, engage and align cooperation efforts with existing fora, working groups etc. Phase 2 (Months 4-6): Dissemination, testing, and iteration of design principles with international partners.

<table>
<tr><td>

- Consumer Advocacy Groups
- Research Institutions
- European Commission (DG Energy, DG Connect)
- National Energy Agencies
- Data Protection Authorities

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Phase 2 (Months 7-18): Development of proposed protocols, standards, and reference architectures.

Phase 3 (Months 19-24): Collaboration with public authorities and industry groups for dissemination and adoption.

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Next steps

- **Establish a Coordinating Committee**: Form a steering group comprising key stakeholders to oversee the action.
- **Engage International Partners**: Initiate collaboration with international organizations and stakeholders.
- **Organise Workshops and Consultations**: Facilitate events to discuss and refine design principles.
- **Define scope of reference architecture**
- **Identify funding**

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Existing funding sources (how)

- No existing funding in place

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Additional budget required (how)

- Full project financing required
- Anticipated total cost: €1M - €1.2M

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2. Designing for new energy systems: Grid usage and management (capacity, aggregation, flexibility & ancillary Services)

Action Title Designing for new energy systems: Grid usage and management (capacity, aggregation, flexibility & ancillary Services)	**Action #:** JA3 **Action status:** Ideation

Action Objective:

- To expand knowledge and drive increased awareness on new and upcoming challenges and opportunities in grid usage and management fit for new energy systems
- Identify practical steps for bridging digital transition maturity in grid usage and management between countries at different stages of the digital energy transition
- Conduct pilots to demonstrate grid planning for optimal use via digital twins, storage/stability services, and management of ancillary services.

Action Description:

When considering Grid management, this must be approached from a future perspective, instead of designing solutions for current problems (e.g. grid congestion), we must identify the optimal system and work backwards to ensure our future energy systems are truly fit for the digital age and the green imperative.

Participating countries are experiencing (and / or communicating) different challenges when it comes to their energy grids based on differing maturity within their green digital energy transition. This offers an opportunity for leaders in this space to create awareness and signpost these challenges, and for those following, to proactively address them. Key examples include the shift from congestion management treating load and feed-in as separate topics, to one where they are combined as part of a decentralised system; as well as data availability and awareness of high voltage vs low voltage congestion as a challenge area. To mitigate this, grid use must be optimised, whilst data-driven strategic grid planning can play a key enabling role.

Grid use and management cuts across a vast array of stakeholders with competing commercial and strategic interests which can result in transparency and collaboration issues - stakeholder engagement will be essential within the action and creating awareness and targeted, impactful messaging will be key for enabling engagement and buy-in to these challenges, from DSOs, to regulators, to consumers and through to public authorities.

The action will design an international framework for the usage, management and planning of grid capacity, including the delivery of simulation services and ancillary support (including flexibility and aggregation of distributed energy resources via demand response, storage, and decentralised generation) to deliver efficient systems and avoid building systems around obstacles such as

congestion.

A core focus will be on modelling integration of flexible assets (like electric vehicles (EVs), batteries, and smart appliances) to optimise grid load and balancing, reduce congestion, and lower energy costs.

The framework will facilitate partnerships among utilities, technology providers, aggregators, and regulators to support interoperability and will ensure inclusion of smaller energy producers, aggregators, and communities within the planning and design phase.

The project will also consider the role of data access and sharing between energy ecosystem stakeholders to support this strategic planning at a pan industry level, increasing transparency and driving collective improvements.

- **Phase 1: Stakeholder mapping, engagement and best practice:** Identification and engagement strategy for stakeholders, particularly around key targeted messaging to drive engagement. Alignment with all grid value chain stakeholders incl. DSOs, regulators, Digital Twins developers, Grid Planners and ancillary service providers etc.: Identify best practice on advanced simulation models and digital twins of electrical grids at national and international levels to support planning and optimization leveraging existing projects and international communities e.g. TwinEU
- **Phase 2: Collaborative future state grid design:** Collectively identify key trends that will impact future grid systems in digital, green decentralised energy systems. Key considerations around enhancing data access and transparency for strategic planning and flexibility services: Work with national data centres and grid operators etc. to identify required data points for effective system modelling, strategic planning and delivery of ancillary services. Create a single vision for future grid requirements.
- **Phase 3**: **Pilot Projects** for deployment of digital twin, integration of Grid Flexibility and Stability Solutions based on outcomes of strategic planning e.g. deployment of assets such as optimised batteries for enhanced grid stability and next-generation controllers for automatic dispatching of ancillary services

Action Owner & supporting stakeholders (who)	**Timeframe (when)**
Confirmed interested parties: • PowereX **Additional interested parties being validated** • In exploration with TNO and other partners	Duration: 3 years M1-6: Phase 1: stakeholder mapping and engagement M7-18: Phase 2: Grid future state design M19-36: Phase 3: Pilot design and implementation

Next steps

- Full consortium mapping and identification of relevant funding opportunities.
- Develop detailed project plan
- Pilot projects identification

Existing funding sources (how)	**Additional budget required (how)**

• No existing funding in place	• Full project financing required • Anticipated total cost: €2M–€2.5M

3. Facilitating International Knowledge Exchange for Energy Sharing groups (communities & hubs)

Action Title Facilitating International Knowledge Exchange for Energy Sharing groups (communities & hubs)	**Action #:** JA2 **Action status**: Ideation

Action Objective:

- To develop a collaborative working group to facilitate the sharing of knowledge, best practices, and case studies on the design, operation, and regulation of energy communities and hubs.
- Empower local aggregator companies, optimise energy community setups, enhance resilience, improve local autonomy, and accelerate the transition to renewable energy at the community level.

Action Description:

Energy sharing groups such as energy communities and energy hubs have experienced significant traction in previous years, recently highlighted by European Commission President Ursula von der Leyen's Mission Letter for the incoming Commission which mandated the inclusion of a Citizens Energy Package focused on consumers and affordability, with energy communities, sharing, and peer to peer exchange a core pillar of this.

Amongst EU countries, there is significant discrepancy in the progress that has been made, for example with the Netherlands far more advanced in its preparedness for inclusion of prosumers, and the aggregation of households and smaller customers into the energy system, vs Slovakia and other Eastern European countries who are still focused on aggregation solutions at an industrial, cluster level, with notable barriers such as energy subsidies preventing consumer-facing smart, aggregation solutions from taking off.

Despite these differences, there is strong opportunity for knowledge exchange and alignment on this topic, with pockets of best practice evident across the EU, and a proliferation of activities looking to progress knowledge in the space. This project will focus on learning from and aligning with these ongoing efforts to identify key opportunities for preparing all stakeholders, from prosumers through to regulators, on how best to implement energy sharing, how to finance projects and incorporate smart energy contracts, and more, be it at a community or industrial cluster level.

Stakeholder analysis and targeted awareness building will be essential for accelerating progress and making meaningful change.

- **Phase 1**: **International Collaboration and Knowledge Sharing**

Establish partnerships between local and international stakeholders—including energy communities, local aggregators, policymakers, and technology providers—to share successful implementation practices and lessons learned from across the EU. Focus areas include community-led energy projects, smart grid integration, and decentralised energy trading and sharing models. As part of this, stakeholders will consider national definitions of energy poverty to allow energy communities to target these groups more easily; strategies for accelerating and facilitating permitting procedures for renewables; strategic stakeholder engagement and advocacy (e.g. DSOs), incentives for the rollout of smart meters, integration with data centres, regulatory frameworks, citizen participation incentives, legal support and community governance models. This list is not designed to be exhaustive.

- **Phase 2**: **Empower Local Aggregators**
  Stakeholders will specifically consider the role that aggregators provide within the implementation of energy sharing groups; the action will identify and address barriers that prevent local aggregator companies from operating energy communities, develop strategies and recommendations to engage DSOs, TSOs and regulatory bodies to enable small companies to increase their participation, and develop business models targeted at increasing uptake of these groups.

- **Phase 3**: **Implementation and Support**
  Utilise the shared knowledge to optimise the design and operation of energy communities and hubs. Provide support for local aggregators to implement best practices, leveraging international insights in a pilot site (to be identified).

Key Considerations:

- **Regulatory Engagement**: Engagement with TSOs and regulatory authorities will be necessary across all participating regions / Member States to ensure the conditions are in place to enable communities and relevant stakeholders to act upon recommendations.

Action Owner & supporting stakeholders (who)	**Timeframe**
Confirmed interested parties: ● G-Institute **Additional interested parties being validated**: ● Energy Community Organizations ● Local Aggregator Companies ● International Energy Agencies ● Transmission System Operators (TSOs) ● Distribution System Operators (DSOs) ● Regulatory Bodies	Duration: 2 years Phase 1 (Months 1-12): Establish partnerships, organise international workshops and conferences for knowledge exchange. Phase 2 (Months 5-12): Develop strategies to empower local aggregators, engage with TSOs and regulators, identify and propose regulatory changes. Phase 3 (Months 13-24): Implement best practices in pilot projects,

<table>
<tr><td></td><td>monitor outcomes, and refine approaches for wider adoption.</td></tr>
<tr><td colspan="2">Next steps
Finalise initial working group / consortium membership including stakeholders from regions demonstrating best practice in energy community deployment;
identify pilot site for downstream implementation and validation of recommendations
Identify public funding call(s) for application</td></tr>
<tr><td>Existing funding sources (how)
No existing funding in place</td><td>Additional budget required (how)
Full project financing required
Anticipated total cost: €1.2M - €1.4M</td></tr>
</table>

4. Best Available Technology (BAT) Open Repository: Curating resources for the Digital Energy Transition

Action Title Best Available Technology (BAT) Open Repository: Curating resources for the Digital Energy Transition	**Action #:** JA4 **Actions status:** ideation

Action objective

- Create a reliable, open information source for stakeholders keen to engage with the green digital energy transition
- Proactively drive knowledge exchange and incorporate the most up-to-date materials relevant for specific priority topics within the transition.

Action Description (what)

Given the complexity and constantly evolving knowledge required for guiding a successful green digital energy transition, having a single, up-to-date source of best practice that can act as guidance for stakeholders across the landscape will be transformational.

This focus on creating a repository rather than a database infers a more active process, with the ambition to create not just a list of available technologies, but instead a platform that is actively maintained via proactive outreach to identify best practice (i.e. amongst those who may not even realise they are examples of best practice), to vet and ensure quality of inputs, to maintain and align to the evolving face of the green digital energy transition, and to proactively promote this resource and key insights to stakeholders in a targeted manner. Whilst this will obviously entail additional resource burdens, the comparative value stakeholders can get from this is significantly higher.

The repository will be designed to be an online, open repository to drive international knowledge transfer in the digital energy transition across the quadruple helix. The repository should be developed with a modular approach, building out iteratively with a 'quality over quantity' principle, with available materials either produced in-house or vetted third-party materials.

Development of the repository will be designed to leverage synergies with other 'one-stop-shop' style information sources and initiatives ranging from the network of European Digital Innovation Hubs through to other Sector working groups and initiatives.

Initial focus areas should align to current priority topics across the current WEnnovate partner geographies and will be evaluated on a regular basis. These include:

- Digital energy infrastructure interoperability mechanisms and adherence to the S2 protocol (JA1)
- Energy groups (i.e. energy communities) (JA2)
- Grid congestion: Capacity, flexibility, aggregation, and strategic planning for RES integration at scale (JA3)

The repository should combine

- Thought leadership
- Practical case studies on successful pilots in relevant industries with clear use cases and benefits
- Sign-posting to relevant standards and reference architectures

Material will be developed for stakeholders across the quadruple helix however will primarily be focused on practical support for policy makers / public authorities and industry / SMEs to facilitate more informed, agile regulatory changes in line with industry trends, and the uptake of relevant solutions by industry.

Key consideration will also be given to the platform governance and particularly the role and identification of contributors and moderators.

Action Owner & supporting stakeholders (who)
Confirmed interested parties:

- G-Institute
- Slovak Innovation & Energy Agency (SIEA)
- Slovak Battery Alliance
- Technical University of Kosice (TUKE): Innovation Hub

Additional interested parties being validated
The action will require input from industry associations, leading academics in the target fields, NGO's, public energy / innovation agencies and private entities supporting the transition.

The repository will be open to contributions from across the EU and beyond and the consortium will look to increase its reach and influence through additional partnerships with EU member states already demonstrating best practice in relevant topics.

Timeframe (when)

- Duration: 3 years
- M1-3: Governance and stakeholder engagement
- M4-6: Content Strategy
- M4-9: Platform Design
- M7-36: Content creation
- M12-18: Initial pilot testing
- M19-36: Evaluation, iteration and expansion

Next steps
Whilst numerous stakeholders have expressed an interest in the topic, a defined consortium to lead these efforts is still required.

Funding will be sought to establish the foundations of the repository alongside organisational budgets.	
Existing funding sources (how) • No existing funding in place	**Additional budget required (how)** • Full project financing required • Anticipated total cost: €2M - €2.4M

5. Advancing digital energy innovation education: Tailored training for leadership and workforce development

Action Title Advancing digital energy innovation education: Tailored training for leadership and workforce development	**Action Reference #:** JA5 **Action status**: Ideation

Action Objective
Work with existing international education institutions, programmes and associations to create and disseminate targeted, mixed education materials to drive

- (a) transition ready workforce better equipped to develop and uptake innovations for the digital energy transition, and to
- (b) leadership and executive level skills for guiding the transition

Action Description
Education of the workforce will be central to a successful green digital energy transition, and will go hand-in-hand with an informed executive / leadership layer that can appropriately direct and oversee the required transformations. This action will focus on partnering with existing HEI / training institutes to deliver two components:

- Creating an executive / leadership green digital energy transition learning academy and targeted course material
- Developing learning materials for cross-sector workforce, with modules targeted at stakeholder groups across the quadruple helix, priority sectors, and incorporating international best practice.

Key considerations will be incorporated around the challenge of accreditation of proposed course materials to incentivise participation, alongside evaluation of other incentives and levers.

This project will ensure alignment with existing EU initiatives such as the Pact for Skills; Partnership for Skills for Digitalisation of Energy and Net Zero Industry Academies which could create significant synergies both as delivery partners, and create shared learnings on routes to accelerated credentials and certification.

Given the focus on upskilling on breakthrough and emerging trends within the transition, a key challenge will be identification of appropriate experts for course material and delivery, particularly combining industry and academia expertise and therefore this will be a foundational activity within the project, and a key pillar will be integrating practical, industry led learning into the materials.

Materials will be produced in a modular fashion with micro-credentials to make them more accessible to those who are not able to / interested in undertaking a full time educational programme. Academic partners will work with their institutions and broader academic networks to ensure appropriate accreditation for said materials to optimise uptake. Where possible materials will

<table>
<tr><td colspan="2">be developed to be open source to increase their dissemination, e.g. via integration with existing platforms such as EIT Deep Tech Talent Initiative.

This action will leverage existing course building expertise and frameworks within the WEnnvoate consortium and adapt them for the needs of energy transition education specifically.

Materials are to be developed and delivered in multiple formats including a combination of targeted workshops; online materials; joint energy innovation master programs, training and online courses. Insights from all other Actions within this action plan will be incorporated into the educational materials to ensure synergies between actions.</td></tr>
<tr><td>Action Owner & supporting stakeholders (who)
Confirmed interested parties:
● TU Delft
● Slovak Innovation & Energy Agency (SIEA)
● Slovak Battery Alliance
● Technical University of Kosice (TUKE): Innovation Hub

Additional interested parties being validated
● Academic institutions
● Additional industry / sector partners to support creation of content materials</td><td>Timeframe
Duration: 3 years
M1-3: Governance and partnership building
M4-9: Needs assessment & expert identification;
M10-15: Content development & accreditation
M16-21: Pilot delivery;
M21-24 Evaluation and iteration;
M25-36 Expanded rollout</td></tr>
<tr><td colspan="2">Next steps
● Full consortium mapping and identification of relevant funding opportunities.
● Develop detailed project plan
● Pilot projects identification</td></tr>
<tr><td>Existing funding sources (how)
● No existing funding in place</td><td>Additional budget required (how)
● Full project financing required
● Anticipated total cost: €1.6M-€2M</td></tr>
</table>

6. Strengthening communication and dissemination networks for the digital energy transition

Action Title Strengthening communication and dissemination networks for the digital energy transition	**Action Reference #:** JA6 **Action status**: Ideation

Action objective

- Connect and improve awareness, signposting and dissemination of existing working groups, initiatives, and associations, to improve collaboration and knowledge exchange across the fragmented green digital energy transition landscape

Action Description (what)
There is a huge amount of will, interest, and effort going into driving the green digital energy transition across Europe and beyond, however much of this is being done in siloed groups, creating a fragmented change landscape where synergies are neither identified, nor realised. The key ambition of this action is to improve awareness across the quadruple helix, of the ongoing work being done for the transition, and to better connect these efforts, to improve their impact. This is relevant for public authorities, industrial associations, NGOs, and many more alike.

A standalone institute, the Energy Innovation Ambassadors Institute, will be established as an effective tool to drive this awareness building, particularly around innovations within the energy sector, and the thought leaders and working groups who are driving these efforts (e.g. ETIP SNET, EDIH etc.) at a cross-EU level. The ambassadors will constitute an expansive network of change makers who will connect stakeholders to relevant working groups across all levels of governance, with localised ambassadors fulfilling an equivalent role within their national context..

Efforts will be equally targeted at those driving social, and technological innovations to achieve the transition.

Awareness raising will be targeted at all participants within the quadruple helix, however specific ambassadors will drive their respective focus areas (i.e. public engagement and acceptance, advocacy at a public authority level, inter-ministerial working groups, industrial association etc.)

The project will produce a communications strategy addressing each target group (and subgroups), core messaging relevant across national borders, and key learnings on successful tactics for political and industrial advocacy and citizen engagement.

Beyond the signposting activities, the Institute will also look to drive broader awareness on key topics such as the following:
Civil society

<table>
<tr><td colspan="2">

Focus on economic benefits of transition for households through energy sharing, resulting monthly / annual bill reductions etc.
Specific attention to debunking of widespread misinformation around safety of digital energy devices (e.g. heat pumps) and climate change (severity, scientific grounding etc.)
Broader education on importance of role of RES within climate transition (resilience through diversification & overcoming historic bias), new roles and opportunities for consumers (financial & societal benefits for prosumers, communities etc.) & security (geopolitical autonomy of sector)

Industry & SMEs

Focus on economic benefits of transition for businesses

Public authorities (ministries, municipalities etc.)

Digitalisation and energy transition as single concept
Digital upskilling programmes for ministries / public authorities
Strategic planning, interconnected nature of transformation with other development areas (AI, data sharing, telecommunications, security)

</td></tr>
<tr><td>
Action Owner & supporting stakeholders (who)

Confirmed interested parties:

Energy Innovation Ambassadors network to be established by WEnnovate consortium members
USF as partner of WIN-WIN EDIH
Design Terminal
SSF
Slovak Innovation & Energy Agency (SIEA)
Technical University of Kosice (TUKE): Innovation Hub

</td><td>
Timeframe (when)

Duration: 2 years
M1-4: Strategic Planning, Governance Setup, stakeholder & communication strategy;
M5-8: Ambassador Network establishment;
M9-15: Pilot testing (communication and outreach strategy);
M16-M24: Evaluation and iteration;
M1-24: Ecosystem monitoring and engagement

</td></tr>
<tr><td colspan="2">
Next steps

Full consortium mapping and identification of relevant funding opportunities.
Develop detailed project plan

</td></tr>
<tr><td>
Existing funding sources (how)

No existing funding in place

</td><td>
Additional budget required (how)

Full project financing required
Anticipated total cost: €1M - €1.2M

</td></tr>
</table>

7. Fostering energy innovation ecosystems for the digital energy transition

Action Title Fostering energy innovation ecosystems for the digital energy transition	**Action Reference #:** JA7 **Action status :** Ideation

Action objective

To create and enhance an interconnected energy innovation ecosystem that supports systemic change in the green and digital energy transition by fostering collaboration, innovation, and governance among diverse stakeholders across Europe, and ultimately increasing the share of renewable and digital technologies in the sector.

Action Description (what)

This action focuses on developing and strengthening an energy innovation ecosystem that brings together diverse stakeholders, including corporates, grid operators, end-users, cooperatives, innovation hubs, and investors, to address the challenges and opportunities of the green and digital energy transition.

Building on foundations: Rather than building a completely new ecosystem, the action will leverage and integrate into existing initiatives, such as the Synergy Hackathon[20]. The target ecosystem will serve as an enabler for systemic change, providing a structured framework for ongoing change management and fostering long-term collaboration among stakeholders.

The ecosystem activities will build on the learned experience of partners within the consortium and provide a variety of services and activities to engage the wider ecosystem, and build and maintain momentum. This will include:

- Strategic design and development sprints that will bring together key expertise to identify and tackle priority challenges aligned to the ecosystem's vision and scope for innovation within the digital energy transition
- A "Digital Energy Hackathon Series" will be organised (annually) to catalyse innovation and strengthen the ecosystem. These hackathons will be a tool to foster interconnectedness, build capacity, and generate breakthrough solutions, ensuring they are embedded into the broader governance and change management processes of the ecosystem.
- Targeted round tables will facilitate strategic conversations to be held between sector leaders to ensure collective alignment on strategy and direction setting for navigating the transition
- Strategic partnership building with event organisers and platform owners will allow the ecosystem to leverage third party partners' existing reach and network, while delivering added benefit and expertise to these existing forums through integrated events

[20] https://synergyhackathon.org/

- Networking facilitation and connectivity will be key to help bring together relevant stakeholders across geographies and sectors to identify and benefit from market synergies
- A core focus on end-user integration throughout will support the Ecosystem to stay true to the vision of a user-centred digital energy transition that truly serves society and not just corporations and governments
- Startup and growth support will be facilitated through the Ecosystem's network of investors, innovators, accelerators, user-group representatives and more, to provide the necessary tools for innovators within the Ecosystem to achieve scale and impact

The Ecosystem will be fundamentally international to support cross-border learning and Single Market impact, however there will be a core focus on local networks and events to build real communities between stakeholders as a key mechanism for driving innovation through both informal and formal interactions.

This activity will leverage networks and synergies with all the other actions identified in these Action Plans at both Joint Programme and National level.

Action Owner & supporting stakeholders (who)

- The coordinating entity is yet to be identified, interested parties being validated.

Confirmed interested parties:

- Design Terminal
- Slovak Innovation & Energy Agency (SIEA)
- G-Institute
- Unify.energy

Additional interested parties being validated

- Educational Institutions: For hosting venues and recruiting participants.
- Energy Companies: To provide real-world problems and mentorship.
- Technology Firms: To supply tools, platforms, and technical support.
- Government Agencies: For policy guidance and potential adoption of solutions.
- Investors
- End users

Timeframe (when)

- Duration: 3 years
- M1-3: Strategic Planning and Ecosystem Framework Design;
- M4-12: Pilot ecosystem integration and collaboration;
- M9-12: Initial hackathon planning;
- M13-36 Ecosystem optimisation and ongoing engagement pilot testing and scaling

Next steps

- Full consortium mapping and identification of relevant funding opportunities.
- Develop detailed project plan

Existing funding sources (how)

- No existing funding in place

Additional budget required (how)

- Full project financing required

	• Anticipated total cost: €1.6M - €2M

Monitoring & Evaluation

Defining a consistent approach to monitoring and evaluation will help establish accountability, improve implementation, and strengthen the Joint Programme's adaptability, ensuring it remains relevant to the transition's needs across participating EU member states, whilst remaining aligned to the latest science and international consensus.

Although WEnnovate itself is only funded until the end of November 2024, the consortium and relevant third parties will continue to collaborate on the target actions to identify / obtain mechanisms to enable their implementation - this is provisional on securing future funding (public and / or private). We have identified potential funding sources based on what is currently publicly available, however this will continue to evolve with the ongoing availability of funding at all levels and support of new partners for consortium building.

As highlighted by the research within the WEnnovate project, a key challenge is limited availability of national funding and a reliance on EU funding, and an increasing need for greater involvement of private finance, for digital energy transition related activities and therefore the WEnnovate partners will be closely monitoring the future release of the Horizon 2025-2027 work package and any match funding opportunities..

To ensure the consortium partners maintain momentum in pursuing the desired outcomes of the Action Plan, we will aim to hold a 6 monthly review meeting regarding funding opportunities and reporting on implementation of the actions that have received funding and areas for collaborative support. This will run until the end of the 3 year window targeted within the Joint Programme and may be incorporated into the management / implementation activities if a future consortium is able to take forward WEnnovate's work.

Upon formal application of each action / the whole Programme for future funding, each action will be reviewed and refined to define specific KPIs, evaluation criteria, and relevant benchmarks against which to assess their success.

Evaluation of the success of the WEnnovate Joint Programme will be done on the basis of successful collaborations, projects awards, and funding raised based on the actions and work prepared in this document and other supporting WEnnovate activities.

Conclusions

This Joint Programme Plan provides a clear and prioritized roadmap for stakeholders in Slovakia, the Netherlands, Hungary, and Ukraine, as well as partners across the European Union, to unlock the next stage of their digital energy transitions. It addresses shared challenges and opportunities, fostering collaboration and knowledge sharing to deliver innovative technological and social solutions essential for a green digital energy future.

While the partner countries are at varying stages of their digital energy journeys, common issues such as gaps in education, awareness, and competencies persist, alongside technological challenges related to decentralization, interoperability, capacity, security, and stability. This Joint Programme Plan directly targets these barriers, focusing on the development of tools, systems, and networks that transcend national contexts and facilitate meaningful progress.

Developed through extensive cooperation among energy system stakeholders, the plan highlights both the opportunities and challenges of fostering cross-border and cross-sector collaboration. Engaging key ecosystem stakeholders has required considerable effort, and more work is necessary to consolidate potential collaborations and overcome existing silos. Despite these hurdles, the Plan itself serves as a critical instrument for driving engagement, building future consortiums, strengthening ecosystem connections, and planning funding pipelines.

The WEnnovate consortium partners remain committed to advancing the actions outlined in this plan and their respective National Action Plans. These efforts will be bolstered by the involvement of stakeholders identified within these documents, as well as new collaborators who can add significant value to the initiatives. By addressing challenges collaboratively, WEnnovate and its partners aim to make a lasting impact on energy systems and the social contexts in which they operate, ensuring the ecosystems achieve outcomes greater than the sum of their parts.

Through sustained commitment and collective action, this Joint Programme Plan lays the foundation for a resilient, secure, inclusive, and innovative digital energy transition across the EU.

Appendices

Appendix 1: Stakeholder engagement

The WEnnovate project was built upon a process of extensive stakeholder engagement, across all four partner countries, and all components of the quadruple helix. With co-creation at the core of our vision, and the desire to have outcomes that represented the lived experience of a diverse array of stakeholders, not just incumbent players and those representing the status quo, each partner began the project with a thorough mapping exercise of key stakeholders within their ecosystems, this was revised on an ongoing basis. Extensive outreach was conducted and stakeholders were targeted according to their sector experience and ability to provide relevant insights for each stage of the stakeholder engagement process.

The project's stakeholder engagement was guided by a clear methodology, stakeholder dialogue framework (D4.1) and Communication Plan (D4.3). The project initially focused on preliminary and in-depth interviews to define an initial mapping of each of the ecosystems.

As the project moved into its latter stages, a more collaborative approach was taken, favouring workshops, 'policy labs' and international sessions to collectively develop and validate proposed recommendations and actions for these Plans. Surveys were also used as a stakeholder engagement tool however this received less traction across the partner ecosystems so direct engagement was prioritised. Below are the key stats regarding the different stages and formats of engagement throughout the project.

It should be noted that as the national action plans and joint programme are inherently linked and designed in parallel, all stakeholder engagement served as inputs for both final Deliverables and therefore this stakeholder engagement summary is applicable to both Deliverables..

Table 1: High level overview of stakeholder engagement.

Number of stakeholders engaged	408
Number of stakeholder co-creation or co-planning meetings	32
Percentage of engaged stakeholders from underrepresented demographics	37%

Table 2: In-depth interviews participants.

Stakeholder group	Hungary	the Netherlands	Slovakia	Ukraine	Stakeholder group total
Civil society	5	4	6	6	**21**
Government/public authorities	3	4	2	2	**11**
Science/research/innovations	2	2	4	3	**11**
Corporate/business/industry	12	11	11	9	**43**
Country Total	**22**	**21**	**23**	**20**	**86**

Table 3: Workshop participants.

Stakeholder group	Hungary	the Netherlands	Slovakia	Ukraine	Stakeholder group total
Civil society	10	9	9	23	**51**
Government/public authorities	5	16	5	27	**53**
Science/research/innovations	5	5	5	55	**70**
Corporate/business/industry	19	22	12	85	**138**
Country Total	**39**	**52**	**31**	**190**	**312**

Table 4: Policy Lab participants.

Stakeholder group	Hungary	the Netherlands	Slovakia	Ukraine	Stakeholder group total
Civil society	2	1	4	4	**11**
Government/public authorities	1	5	6	3	**15**

Science/research/innovations	3	3	2	7	**15**
Corporate/business/industry	4	3	4	5	**16**
Country Total	**10**	**12**	**16**	**19**	**57**

Table 5: International validation session participants.

EU	Hungary	the Netherlands	Slovakia	Ukraine	Total
4	1	8	5	5	**23**

Table 6: Survey participants.

Stakeholder group	Stakeholder group total
Civil society	**6**
Government/public authorities	**3**
Science/research/innovations	**9**
Corporate/business/industry	**34**
Total	**52**

Appendix 2: Horizon Europe '25/'26 Calls of interest

An initial scan of open source documentation on provisional Horizon Europe Grants for the upcoming '25/'26 Work Programme was undertaken to identify relevant calls of interest to the activities referenced across the National Action Plans and Joint Programme. The primary calls of relevance are highlighted here; however, this list will be monitored and reviewed in line with formal publication of the finalised Work Programme update.

No.	Topic	Type of action
Batteries (Batt4EU Partnership)		
1.	HORIZON-CL5-2025-D2-01: Development of Sustainable and Design-to-Cost Batteries with (Energy-)Efficient Manufacturing Processes and Based on Advanced and Safer Materials	IA
2.	HORIZON-CL5-2025-D2-02: Cost-effective next-generation batteries for long-duration stationary storage	RIA
3.	HORIZON-CL5-2025-D2-03-SRP: Sustainable processing and refining of raw materials to produce battery grade Li-ion battery materials	IA
4.	HORIZON-CL5-2025-D2-04: Integrating advanced material, cell design and manufacturing development for high-performance batteries aimed at mobility	RIA
5.	HORIZON-CL5-2025-D2-05: Accelerated multi-physical and virtual testing for battery aging, reliability, and safety evaluation	IA
6.	HORIZON-CL5-2025-D2-06: Battery Technology and Innovation Platform and Information Observatory	CSA
7.	HORIZON-CL5-2025-D2-07: Fostering an Excellent Battery R&I Community for Better Projects and Innovation Uptake	CSA
Global leadership in renewable energy		
8.	HORIZON-CL5-2025-D3-03: Novel approaches to geothermal resources development	IA
9.	HORIZON-CL5-2025-D3-04-SRP: Development of hydropower technologies and/or water management schemes allowing for win-win situation of flexible hydropower and biodiversity	RIA

	improvement	
10.	HORIZON-CL5-2025-D3-05: Demonstration of thermal energy storage solutions for solar thermal plants.	IA
11.	HORIZON-CL5-2025-D3-06: Innovative manufacturing of wind energy technologies	IA
12.	HORIZON-CL5-2025-D3-07: More reliable and easier to operate and maintain wind energy systems	RIA
13.	HORIZON-CL5-2025-D3-08: Understand and minimise the environmental impacts of wind energy	RIA
14.	HORIZON-CL5-2025-D3-09: Alternative Silicon Growth Technologies (from both liquid and gaseous phase) for PV Applications	IA
15.	HORIZON-CL5-2025-D3-10: Towards commercialisation of Perovskite PV and development of dedicated manufacturing equipment	IA
16.	HORIZON-CL5-2025-D3-11: Novel inverter technologies and flexibility in PV systems	IA
17.	HORIZON-CL5-2025-D3-12: Extending the lifetime of PV modules	RIA
18.	HORIZON-CL5-2025-D3-14: Development of innovative solutions strengthening the security of renewable energy value chains	RIA
19.	HORIZON-CL5-2025-D3-16: Support to the SET Plan stakeholder fora	CSA
Energy systems, grids & storage		
20.	HORIZON-CL5-2025-D3-17: Control and operation tools for a RES-based energy system	IA
21.	HORIZON-CL5-2025-D3-18: Next generation distribution substation for increasing the system resilience	IA
22.	HORIZON-CL5-2025-D3-19: Innovation solutions for a digital spine in the EU energy system	IA
23.	HORIZON-CL5-2025-D3-20: Innovative tools and services to manage and empower energy communities	IA
24.	HORIZON-CL5-2025-D3-21: Cross-regional network and market model for optimization of long duration storage for planning of transmission and distribution networks	RIA
25.	HORIZON-CL5-2025-D3-22: Underground Thermal Energy Storage in	IA

	dense urban areas	
26.	HORIZON-CL5-2025-D3-23: Critical elements for energy security of grid and storage technologies	IA
Carbon Capture, Utilization and Storage (CCUS)		
27.	HORIZON-CL5-2025-D3-24: New CO2 capture technologies	RIA
28.	HORIZON-CL5-2025-D3-26: Investment atlas of potential CO2 storage sites	CSA
Cross-cutting issues		
29.	HORIZON-CL5-2025-D3-27: Clean Energy Transition Co-funded Partnership	Co-funded
Highly energy-efficient and climate neutral European building stock		
30.	HORIZON-CL5-2025-D4-01: On-site innovative robotics and automated solutions and techniques for more sustainable and less disruptive building construction and renovation	RIA
31.	HORIZON-CL5-2025-D4-02-SRP: Smarter buildings as part of the energy system for increased efficiency and flexibility	IA
32.	HORIZON-CL5-2025-D4-03: Innovative pathways for low carbon and climate resilient building stock and built environment	RIA
33.	HORIZON-CL5-2025-D4-04: Innovative approaches for autonomous, smart, climate neutral and inclusive Positive Energy Districts	IA
34.	HORIZON-CL5-2025-D4-05: Optimal combination of circular principles, low embodied carbon construction products, and technical building systems for climate neutral buildings	RIA
Other Actions		
35.	Contribution to InvestEU blending operation under the Green Transition product	Indirectly managed action
36.	HORIZON-CL4-INDUSTRY-2025-01-MATERIALS-61: Technologies for critical raw materials and strategic raw materials from End of Life products	IA
37	HORIZON-CL4-INDUSTRY-2025-01-TWIN-TRANSITION-31: From heat-driven processes to the use of mechanical and electric forces	IA
38.	HORIZON-CL4-INDUSTRY-2025-01-TWIN-TRANSITION-32: Green and	IA

	resilient flexible production processes	
39.	HORIZON-CL4-INDUSTRY-2025-01-TWIN-TRANSITION-34: Smart integration of net zero technologies into Energy Intensive industries	IA

Appendix 3: Existing and targeted areas of best practice

Initial discussions amongst consortium members and stakeholders across the participating ecosystems have highlighted key existing best practices at a national level, and targeted areas for future learning, in the following areas. This list will be maintained as a live document and iterated as part of the post-project activities of the WEnnovate programme.

Existing best practises to share:

- Transparency on congestion - TSO congestion, simulations, digital twins to support planning and mitigate against challenges
- S2 protocol and need for interoperability across the system
- The interoperability of charging infrastructure for EV
- Initial progress towards building reference architecture for energy communities
- Energy hubs and networks for knowledge sharing
- Energy data centres for data-driven management of the transition
- Cybersecurity innovations for a resilient energy system

Best practises desired:

- Advocacy and strategies for engaging and influencing public authorities on the importance of digitalisation.
- Energy communities
- Flexible & agile regulatory mechanisms for driving experimentation and innovation (e.g. deregulated zones, large-scale sandboxes & living labs etc.)

Appendix 4: List of WEnnovate deliverables referenced

Document	Source
D3.1: 4 National Deeptech Ecosystem Maps	Link
D3.2: Report of needs, problems, and obstacles in countries-participants	Link
D.5.1: List of Recommendations for the Action Plan with Buy-in from Stakeholder Dialogue	Link
D5.2 4 National Action plan(s)	Link


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