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White-paper for high quality deep-tech ecosystems to support energy transition

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White-paper for high quality deep-tech ecosystems to support energy transition

In a time of rapid technological advancements and pressing environmental challenges, fostering an agile, adaptive approach to energy transition. However, a critical knowledge gap persists, particularly regarding the applications and contributions of deep-tech innovations in advancing sustainable energy systems. Decision-makers, industry, and the public often lack the necessary awareness and understanding of how these advanced technologies can drive efficiency, resilience, and decarbonisation. This knowledge disparity results in fragmented visions across Member States, delaying the adoption of foundational building blocks necessary for a robust energy ecosystem.

Energy transition is not a solitary endeavour; it requires a resilient ecosystem where policymakers, innovators, and communities actively co-create transformative solutions. Yet, decision-making structures that operate in isolation, removed from practical realities, often hinder progress. When confined to "elephant-bone towers," policymakers may overlook the intricate dynamics of deep-tech and energy sectors, missing critical opportunities for impactful change. Without a cohesive understanding of deep-tech's role, policymakers risk missing opportunities to implement transformative changes. Businesses face challenges in aligning their innovations with policy frameworks, while society at large struggles to grasp the tangible benefits of these technologies. This white paper seeks to bridge these gaps, offering actionable insights into how deep-tech applications can unlock new opportunities in the energy sector, foster consensus, and generate societal and environmental benefits.

Drawing on the findings of WEnnovate project's experience, this white paper distills key insights and offers strategic recommendations to foster an ideal ecosystem for deep-tech, emphasising adaptability, inclusivity, and proactive decision-making. By addressing these challenges, we aim to empower stakeholders with the knowledge to catalyse meaningful progress in Europe's digital and green transitions.

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WEnnovate framework and methodology for energy ecosystem change

The WEnnovate project employed various models and processes throughout the project's lifecycle, with the primary model that guided the stakeholder engagement and analysis phase of our work (Fig. 2) informed by other leading transition and digital energy frameworks. More specifically, the project drew on the Dutch DRIFT model (Fig. 4) for transition management and on DG ENER's framework for digitalising and decarbonising the energy sector (Fig. 3).

Framework for facilitating transition of energy ecosystem

The WEnnovate project utilised a structured approach to address the complexities of the digital energy transition. A six-focus-area framework (Fig2) was identified and refined, facilitating targeted discussions with decision-makers and stakeholders. This framework helped shape actionable strategies for integrating digitalisation, fostering collaboration, and enhancing the adoption of innovative energy solutions. By aligning technological innovation with policy, market needs, and societal benefits, the framework provides a cohesive pathway to navigate the transition.

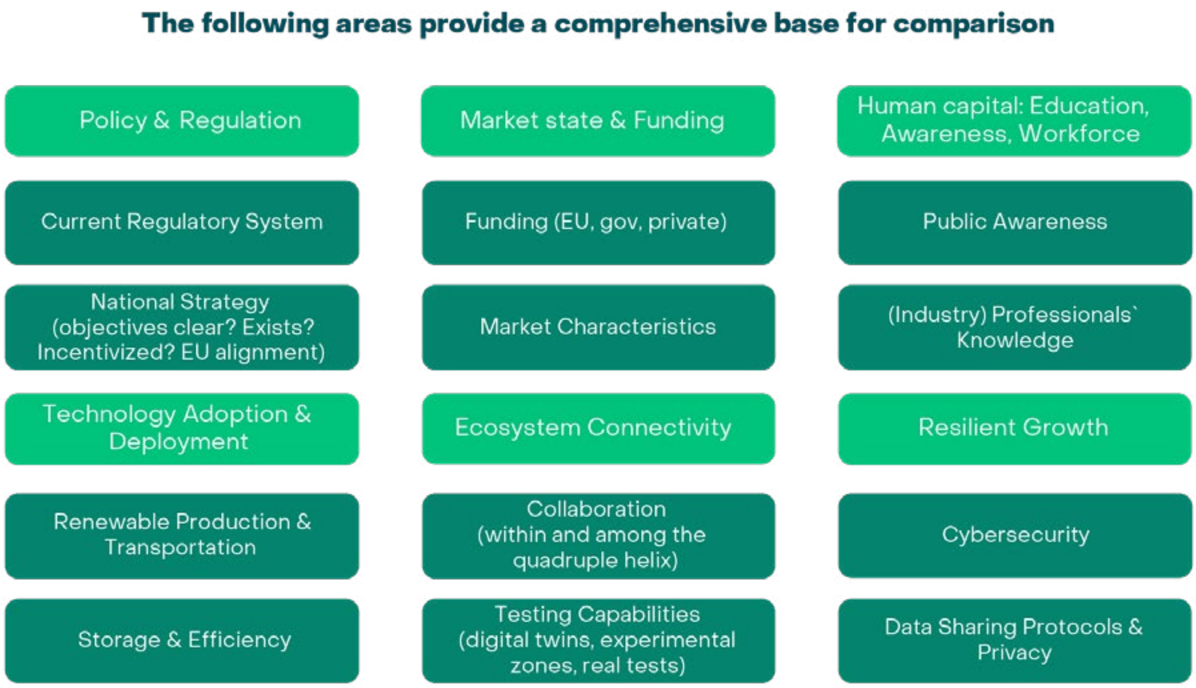


Fig. 2: WEnnovate's framework for the digital energy transition

Transition model: Leveraging the DRIFT methodology

Fig. 3: Priorities from "Digitalising the Energy System—EU Action Plan"

The WEnnovate project approached the challenge of addressing the digital energy transition through the lens of the DRIFT model (Fig 4.), as developed The Dutch Research Institute For Transitions. Rotterdam, The Netherlands[1]. This methodology is rooted in transition management principles, aiming to address societal and technological shifts in dynamic fields like energy transition. 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.

The X-curve diagrams and transition management concepts are highly relevant to understanding how deep-tech innovations can drive the energy transition. The X-curve illustrates the dual processes of building up new systems while breaking down old ones, which is essential in the shift toward sustainable energy solutions. This process mirrors the trajectory deep-tech innovations follow during disruptive transitions, particularly within the energy sector.

Deep-tech innovations, by their nature, address fundamental scientific and engineering challenges, which are crucial for solving the complex problems inherent in energy transitions. The X-curve and transition management methodology from the DRIFT framework can guide how these innovations should be implemented, scaled, and institutionalised.

Fig. 4 - X-curve from the DRIFT transition model

1 https://drift.eur.nl/en/about-drift/transitions/

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.

DRIFT methodology with its X-curve concept provide a roadmap for how deep-tech innovations can effectively contribute to the energy transition. By facilitating early experimentation, supporting scale-up through institutionalisation, and managing the chaos inherent in such disruptive changes, this framework helps ensure that deep-tech solutions can transform energy systems and accelerate the transition to a sustainable, resilient future.

Collaborative and inclusive process

The methodology employed by WEnnovate emphasised collaboration and inclusivity, ensuring alignment with the needs of diverse stakeholders. The creation of four National Action Plans—covering Slovakia, the Netherlands, Ukraine, and Hungary—was informed by:

- Desktop analysis, interviews, and surveys to gather baseline data and insights.
- Multi-stakeholder workshops and review sessions to validate findings and co-develop actions.
- Integration of contributions from third-party stakeholders, alongside consortium-led initiatives seeking partnerships.

WEnnovate engaged stakeholders to ensure proposed actions build on existing efforts and align with EU objectives while addressing regional transition needs. Recognising the complexity of the digital energy transition, the project emphasised inclusivity and diverse perspectives, using the DRIFT methodology and the quadruple helix model to integrate technological and social innovation for equitable and just outcomes.

Stakeholders by the quadruple helix model:

- **Academia:** Universities and research institutions contributing expertise.
- **Industry:** Energy companies, technology providers, and startups driving innovation.
- **Government:** Authorities providing policy and regulatory support.
- **Civil Society:** Consumers and communities representing societal needs.

Special emphasis was placed on engaging underrepresented groups, including new market entrants and female leaders, to promote diversity in decision-making. This inclusive approach was critical for developing solutions that address the societal and economic complexities of the energy transition.

Alignment on shared priorities

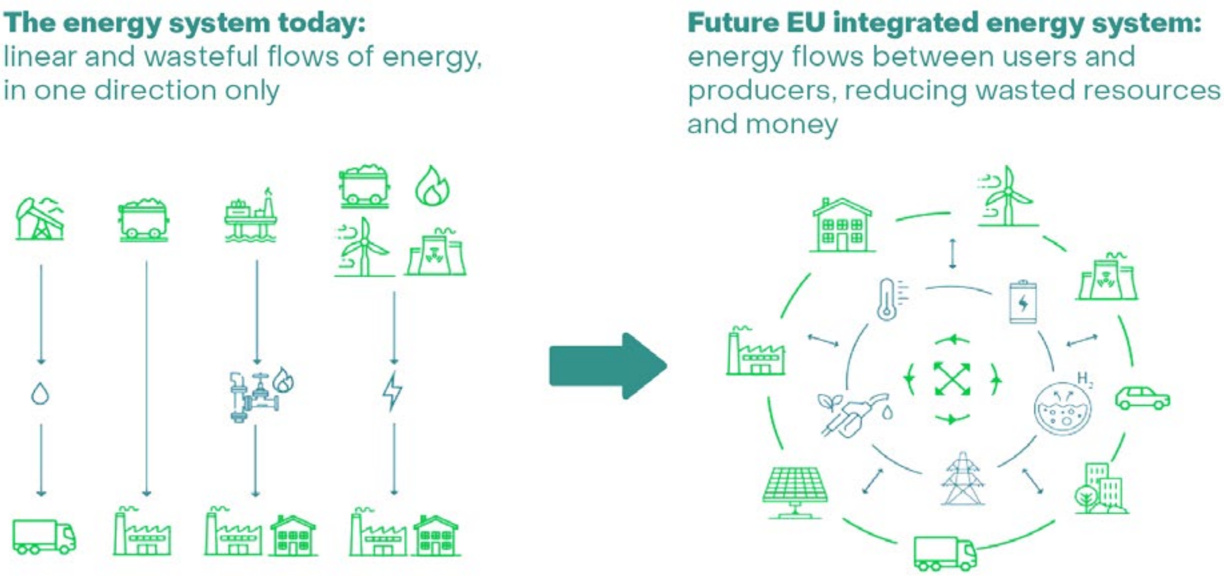
The WEnnovate project's methodology demonstrates the value of participatory and inclusive processes, providing a replicable model for transforming energy ecosystems. The identified actions in the action plans stem from diverse stakeholder engagement and remain open to broader third-party support. By understanding the state of the digital energy transition, the consortium built on existing efforts to aligns shared priorities across regions, offering a unified vision for an inclusive energy ecosystem.

European ambitions for the digital energy transition

The European Union is pursuing an ambitious plan to digitise its energy system, aiming to create a smarter, more sustainable, and interactive energy ecosystem. By 2030, the EU targets a 55% reduction in greenhouse gas emissions, a 45% share of renewable energy, and a significant expansion of renewable capacity. This includes increasing wind and solar generation capacity from 400 GW in 2022 to 1,000 GW, deploying 320 GW of solar photovoltaic capacity by 2025, and nearly 600 GW by the decade's end. Supporting these goals, the EU is also planning for 317 GW of offshore renewable energy.

To navigate this complex transition, the EU has introduced the **Digitalising the Energy System - EU Action Plan (COM/2022/552)**, alongside key policy measures and directives. Updates to frameworks such as the Renewable Energy Directive (REDIII), Energy Performance of Buildings Directive (EPBD), and Energy Efficiency Directive (EED) complement newer regulations like the Alternative Fuels Infrastructure Regulation (AFIR). Recent additions, including the Wind Power Package and Grid Package, bolster the infrastructure needed for renewable integration and grid modernisation.

A decentralised energy mix is central to the EU's strategy, focusing on smart grids to enhance efficiency, reliability, and security while integrating variable renewable power sources. The transition also requires flexibility measures to ensure supply and demand can adapt to changing conditions. Deeper sectoral integration, increased consumer engagement, demand-side flexibility, enhanced energy trading, and innovative regulatory frameworks will further accelerate this transformation.



Digitalisation as a Cornerstone

Advanced technologies like IoT, smart meters, 5G and 6G networks, cloud-edge computing, and digital twins are critical to optimising energy consumption and grid management. A pan-European energy data space will facilitate data sharing and drive innovation, improving market participation and collaboration. Cybersecurity, consumer data protection, and interoperability will remain top priorities.

To meet its ambitious goals, the EU estimates €584 billion in investments in electricity grids by 2030, with significant focus on digitalisation. This includes infrastructure to support the deployment of 10 million heat pumps and 30 million zero-emission vehicles. The **Digital Spine** initiative will bridge the investment gap by leveraging digital technologies, enhancing sectoral decentralisation, and optimising renewable energy use while reducing reliance on extensive physical infrastructure.

Challenges and Barriers

Despite progress, the digital energy transition faces challenges in four key areas:

1. **Technical**: Delayed smart meter deployment, limited digitalisation at the distribution level, and prolonged grid connection processes.
2. **Economic**: High upfront costs for equipment and operational expenses hinder adoption.
3. **Regulatory**: Misalignment between national and EU regulations complicates implementation.
4. **Societal**: Limited consumer awareness and workforce skills slow widespread adoption.

As the EU moves forward, emphasis on cybersecurity and consumer empowerment, particularly for vulnerable populations, will ensure a resilient, inclusive, and sustainable energy future. This transformation not only supports climate goals but also strengthens Europe's long-term competitiveness on the global stage

Vision on ideal ecosystem to accelerate energy transition with deep-tech

The vision for an ideal ecosystem to accelerate the energy transition through deep-tech innovations, as shaped by WEnnovate's extensive research and stakeholder engagement, highlights the need for a collaborative, multidisciplinary structure. This ecosystem integrates cutting-edge technologies within a responsive and supportive framework, creating an environment where stakeholders can address the challenges of the energy transition while capitalising on the transformative potential of deep-tech solutions.

An ideal energy ecosystem should not merely adapt to change but actively anticipate and drive it, fostering inclusivity and resilience across all levels. Recognising the multifaceted nature of the energy transition, this vision focuses on six interconnected pillars, each critical for enabling systemic change:

1. **Policy and regulation:** A dynamic regulatory environment is vital to support deep-tech innovation. Regulations must be adaptable, forward-looking, and conducive to experimentation. Introducing regulatory sandboxes and field labs provides controlled settings for piloting innovative energy solutions such as blockchain-based trading, IoT-driven energy monitoring, and AI-powered grid optimisation.

   Equally important is the establishment of frameworks for digital twins to model and simulate energy systems, as well as the standardisation of data-sharing protocols to ensure seamless interoperability. Policies that promote flexibility markets, empowering consumers to actively participate in energy balancing, can significantly enhance the integration of renewable energy sources.

   A shared vision, articulated through strategic collaboration across academia, industry, government, and civil society (the quadruple helix), will further align national strategies with EU directives, accelerating the pace of digital energy transformation.

2. **Market state and funding**:The high capital intensity and perceived risks associated with emerging technologies can create significant barriers to entry, particularly for SMEs and startups. An ideal ecosystem offers accessible funding mechanisms tailored to different innovation stages.

   This includes subsidies, grants, and public-private partnerships to de-risk investments and support the digital transformation of traditional energy sectors. Funding models should prioritise scalability, enabling technologies to move from pilot projects to widespread implementation. Building cross-border funding networks can amplify the impact of investments, fostering innovation at both national and EU levels.

3. **Human capital**: The energy transition demands a skilled, digitally-literate workforce capable of managing complex deep-tech innovations. Targeted investments in education and capacity-building are essential.

   Universities should develop interdisciplinary programs combining engineering, digital skills, and business acumen to prepare future energy leaders. Vocational training, online courses, and workshops can upskill existing professionals in areas such as AI-driven energy systems, IoT solutions, and data analytics.

   Public awareness campaigns play a crucial role in fostering societal trust and engagement with digital and renewable energy technologies. Such initiatives not only drive adoption but also create a groundswell of support for broader policy and industry changes.

4. **Technology adoption and deployment**: Digitalisation underpins the transition to a decentralised, renewable energy ecosystem. Widespread deployment of smart grids, IoT-enabled devices, and AI-driven analytics is essential to optimise energy production, distribution, and consumption.

   The ecosystem must address integration challenges, breaking down silos between traditional energy systems and digital technologies. Encouraging cross-sector collaboration enables data and innovation to flow seamlessly, creating a dynamic environment where solutions can scale rapidly.

   Emphasising cybersecurity is critical to ensuring the reliability and resilience of digital systems, fostering confidence among stakeholders..

5. **Ecosystem connectivity**: An inclusive energy transition requires active co-creation among diverse stakeholders. Establishing regional innovation hubs can serve as focal points for collaboration, while knowledge-sharing platforms ensure the dissemination of best practices and lessons learned.

   Events such as hackathons, workshops, and policy roundtables can align objectives across sectors and geographies, fostering a shared understanding of challenges and solutions. Connectivity ensures that innovation is not limited to urban centres but extends to underrepresented and rural areas.

6. **Resilient growth**: To prevent fragmentation, the ecosystem must prioritise interoperability, open communication standards, and transparent data-sharing practices. These measures enable cohesive management of decentralised energy systems and ensure that innovations are scalable across regions and sectors.

   A robust cybersecurity framework, integrated with regulatory guidelines, safeguards against emerging threats in increasingly digital energy systems. Social innovation, such as energy-sharing communities and decentralised grids, must be equally prioritised to ensure inclusivity and equitable benefits for all.

This vision for an ideal energy ecosystem draws on WEnnovate's findings and practical experiences, addressing the key areas that need transformation to accelerate the energy transition through deep-tech innovations. By advancing policy and regulatory frameworks, improving funding mechanisms, building human capital, scaling technology deployment, fostering collaboration, and ensuring resilience, the energy sector can evolve into a dynamic, inclusive, and sustainable system.

This approach is essential to meet ambitious goals for carbon neutrality and energy efficiency while driving Europe's leadership in energy innovation. Through collaborative efforts and targeted actions, the energy transition can create widespread benefits, enabling technological advancement and societal progress in equal measure.