wennovate

D3.1: 4 National Deeptech Ecosystem Maps

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Introduction and methodology

WEnnovate project focuses on deep tech and digital innovations for the energy transition (SDG 7 – Affordable and Clean Energy) in which Europe can take a leading position. WEnnovate partners are committed to this consortium for the long-term as this collaboration will accelerate the adoption of the European energy directives – Local Energy Communities, Clean Energy for All, Energy Sharing – into the institutions, markets and innovation agendas of the member states

The understanding of the consortium is "that the current national innovation ecosystems are not interconnected, dynamic, open, inclusive and gender neutral enough to drive innovation in the right direction to strengthen the innovation performance of our economy leading to a more competitive and more sustainable green economy.

Energy is central to the European Union's transition to climate neutrality by 2050, in line with the European Green Deal. Responsible for more than 75% of greenhouse gas emissions in the EU, the energy sector is undergoing a profound transformation towards a net-zero economy.

The green and digital energy transition will require innovation beyond the traditional focus on science and technology. The European Green Deal, the EU's growth strategy, calls for the EU to become a fair and prosperous society where economic growth is not linked to the use of resources.

Research and innovation (R&I) plays an important transformation role, offering sustainable solutions to social, economic, environmental and political challenges, using new technological advances, both in key digital industries and in green technologies.

Under the energy transition, the projects and initiatives aim at supporting the transferable and scalable innovative solutions in real-life settings for economically viable, smarter and more integrated local energy networks, zero carbon and demand driven while empowering citizens and stakeholders to accelerate the transition.

Also the crucial aspect of green and digital energy transition is the promotion of societal awareness and participation. Key objectives of green and digital energy transition include enhancing energy efficiency, reducing carbon emissions, promoting sustainable use of natural resources, minimising environmental pollution, and increasing societal participation. So, collaboration among different sectors of society, including businesses, non-governmental organisations, and governments, is essential in this process.

Digitalisation plays a pivotal role in the energy transition, enabling more efficient and flexible energy systems that can adapt to the increasing integration of renewable energy sources. As countries strive to meet their climate goals, digital solutions are essential for optimising energy management, improving grid stability, and fostering innovation across the sector. These ecosystem maps aim to highlight the importance of digitalisation in driving the energy transition and to provide actionable insights for enhancing the innovation capacity of the energy sector in each country.

Digitalisation is essential for the energy transition as it enhances efficiency, reliability, and sustainability across energy systems. By optimising energy production, distribution, and consumption through advanced analytics and real-time data, digital technologies help reduce waste and lower costs. They are also critical for integrating renewable energy sources, managing grid operations, and empowering consumers with tools like smart meters and energy management systems.

Moreover, digitalisation supports data-driven decision-making, enabling better planning and forecasting. It also fosters new business models such as peer-to-peer energy trading and virtual power plants, which offer more flexible and personalised energy solutions. By facilitating the integration of renewable sources and reducing carbon emissions, digital technologies play a crucial role in advancing sustainability and decarbonisation goals.

As part of the WEnnovate project four comprehensive ecosystem maps were created that present the current state and challenges of the deeptech innovation ecosystems in the energy sectors of the Netherlands, Hungary, Slovakia, and Ukraine. These maps were developed to provide a clear understanding of the strengths, weaknesses, opportunities, and threats within each country's energy innovation landscape, helping stakeholders to identify key areas for intervention and collaboration. The creation of these ecosystem maps involved a thorough process of desk research, ecosystem mapping, interviews, and case studies.

In the first and exploratory phase partners identified how ecosystems are built in Hungary, the Netherlands, Slovakia and Ukraine. The partners collected data on national energy innovation ecosystems to map them for analysing and comparing collected data for overview and insights of aligning different ecosystems of the partner countries. Energy innovation agendas, strategies, policies, plans, activities, relevant actors are in focus in order to reveal the most important topics to discuss in dialogues among stakeholders and develop policy recommendations.

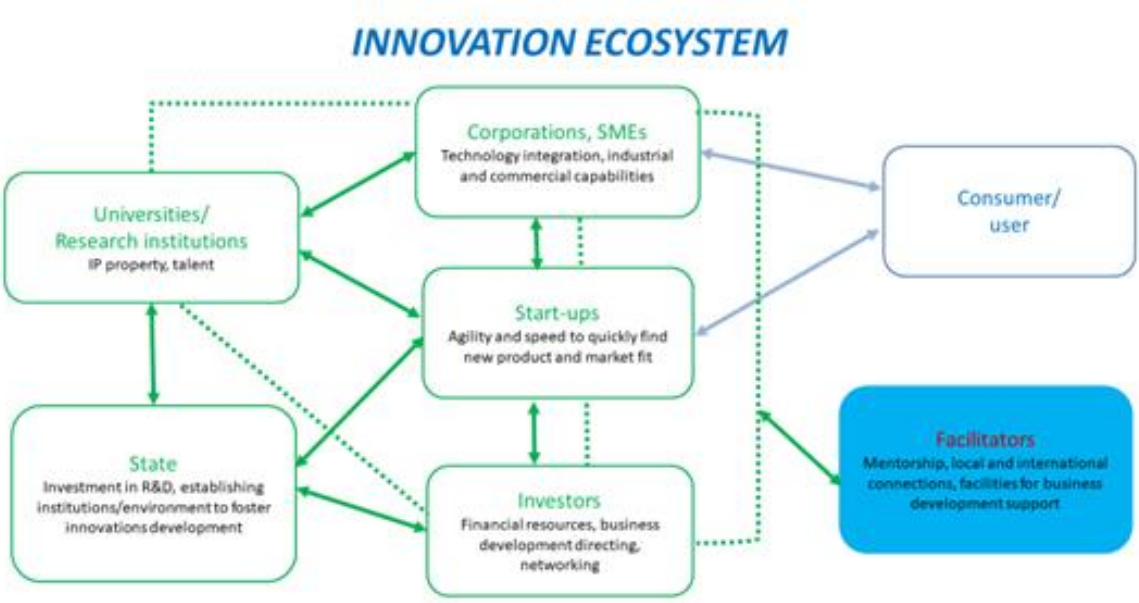


Figure 1: Innovation ecosystem actors

WEnnovate understands the 'innovation ecosystem' as close to 'entrepreneurial ecosystem' and such that creates the environment for innovative teams and companies' emergence and growth. Actors in innovation ecosystems form a community that supports one another through collaboration, sharing of values and resources (see figure 1)[1]

Innovation for the purpose of research and mapping is defined as use of new ideas, products or methods where they have not been used before.

Innovations are based on the results of new technological developments, new technology combinations, or the use of other knowledge, acquired by the entity.

Terms in the research are used in the meaning of Frascati Manual (2015)[2] and Oslo Manual (2018)[3]. Terms not included in manuals are defined in the Glossary in Appendix.

Based on the definition of Isenberg, D.[4], we develop the definition of the innovation ecosystem as a product of three elements:

1. the surrounding environment (including science, research and innovation system at European and national level; energy system, the business environment and investment climate in a country)
2. its interacting actors and connections between them (see figure 1),
3. the evolving culture and attitudes.

The science, research and innovation system is a system of interconnected organisations and institutions involved in the processes of conducting scientific research and development and creating innovations, organisational and financial support structures for research and innovation as well as in the implementation of the results of R&D and the promotion of innovations into the real economy.

The business environment, as the Donor Committee for Enterprise Development (DCED) defines it, is a complex of policy, legal, institutional and regulatory conditions that govern business activity[5].

The business environment is a subset of the investment climate, which takes a broader view of a country's competitiveness. As part of the investment climate, the DCED differentiates between seven domains:

- financial markets, which include access to finance, financial regulations, etc.;
- the rule of law, meaning legal rights which can, for instance, inhibit corruption or regulate the business registration process;
- human resources (HR) and skills, e.g. the technical and vocational education and skills of actors, etc.;
- economic predictability, meaning the overall macroeconomic stability and growth path;
- infrastructure, meaning the technical structures, e.g. roads, telecommunication, energy;
- political situation, which ensures planning security and increases risk tolerance among MSMEs;
- labour markets, meaning the availability of skilled workers and sufficient matchmaking between the work supply and the work demand.

The culture of a society has a large impact on the innovation ecosystems. It affects individuals' attitudes towards entrepreneurship and innovation therefore the likelihood of becoming an entrepreneur/innovator. Culture and attitude, alongside social protection schemes, are important factors that determine a country's level of innovation[6]

Research design was developed to clearly define all the steps to be taken throughout the mapping process. Desk research and field research methods of data collection was used. Desk research was conducted to define:

- energy systems state and future energy transitions trajectories for each country;
- science, research and innovation system in each country;
- business environment and investment climate in each country;
- culture and attitudes to innovation in each country/regions NUTS 1&2 level/sector and for articulating and investigating all types of innovation ecosystems at each country (Regional innovation ecosystems - Smart Specialization based, Sectoral (energy) ecosystems, project-based ecosystems)

In-depth and semi-structured interviews conducted (up to 20 per country). Online questionnaire, focus-groups and other forms of stakeholder dialogues were used to identify needs, challenges, suggestions and success stories (cases) from the ecosystems.

Ecosystem map for each countries presented according to the following structure:

1. General country overview
2. Energy system state and challenges
3. Functional Innovation ecosystem overview: R&I, Business environment, Investment climate, culture
4. Innovation ecosystems
    a. Regional innovation ecosystem
    b. Sectoral innovation ecosystem
    c. Project/programme-based innovation ecosystem
5. Cases

[1] adapted from Deep Tech: The Great Wave of Innovation
https://hello-tomorrow.org/deep-tech-observatory/the-dawn-of-the-deep-tech-ecosystem
[2] https://www.oecd.org/en/publications/2015/10/frascati-manual-2015_g1g57dcb.html
[3] https://www.oecd.org/en/publications/oslo-manual-2018_9789264304604-en.html
[4] Isenberg, D., The entrepreneurship ecosystem strategy as a new paradigm for economic policy: principles for cultivating entrepreneurship, Babson Entrepreneurship Ecosystem Project, Babson College, Babson Park, MA, 2011.
[5] Isenberg, D., The entrepreneurship ecosystem strategy as a new paradigm for economic policy: principles for cultivating entrepreneurship, Babson Entrepreneurship Ecosystem Project, Babson College, Babson Park, MA, 2011. In
OECD, Entrepreneurial Ecosystems and Growth Oriented Entrepreneurship, OECD, Paris, 2014
https://www.oecd.org/cfe/leed/Entrepreneurial-ecosystems.pdf
[6] https://www.giz.de/de/downloads/giz2018-en-guide-mapping-entrepreneurial-ecosystem.pdf

1. Hungary

Country profile[7]:

Region: EUR

Income: High

Population (mn): 10

GDP, PPP$ (bn): 409.8

GDP per capita, PPP$: 42,132

Global Innovation Index, rank: 35

Total energy consumption per capita, kWh[8]: 2660

1.1 Energy Systems State and Challenges

Hungary's energy demand is considerable, with domestic production meeting only one-third of the country's needs while two-thirds are met through imports. Historically, the country's electricity supply was heavily reliant on fossil fuels and nuclear power. Currently, renewable energy sources are gradually contributing more to the energy mix, although nuclear power remains dominant, providing 40% of the electricity. The Paks Nuclear Power Plant expansion is expected to more than double current capacity up to 4400 MW by the early 2030s. Combined with the lifetime extension of the older units, nuclear component is set to provide the fundament of base load supply through the 2030s and 2040s.

Hungary has a significant dependence on third countries for all main energy sources, with Russia historically the main supplier of both fossil fuel imports and nuclear fuel supplies (in 2022 Russia accounted for nearly ca.80% of natural gas, oil, and nuclear fuel). Hungary's heavy dependence on imports, highlights the issue of energy security that needs to be addressed.

Total energy supply (TES) includes all the energy produced in or imported to a country, minus that which is exported or stored. It represents all the energy required to supply end users in the country. The largest sources of energy in Hungary 32% oil and 32% natural gas (2022, IEA).

[7] https://www.wipo.int/edocs/pubdocs/en/wipo-pub-2000-2023-en-main-report-global-innovation-index-2023-16th-edition.pdf

[8] https://www.iea.org/countries/hungary/energy-mix

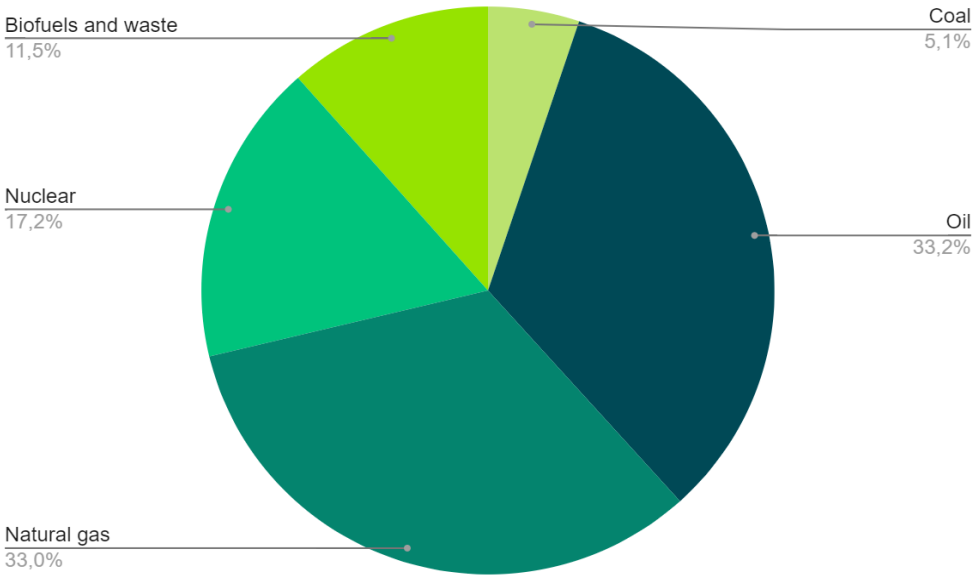


Figure 2: Energy sources in Hungary (2022)

The Hungarian energy system is characterised by the prevalence of fossil fuels for energy consumption. At a domestic production level, nuclear power is Hungary's primary source of electricity consumption at c. 51% ahead of natural gas (c.22%) and coal (c.10%). The share of renewables is below 15%. In the context of Hungary's energy transition, it is important to highlight a significant distinction compared to many other countries in the region, such as the Czech Republic, Poland, Romania, and Bulgaria, as well as the Balkans. Hungary's energy mix has a notably small proportion of coal. This positions Hungary as a low carbon-dependent country within Central and Eastern Europe. However, this also means that further reducing carbon emissions is relatively expensive, as it primarily involves replacing natural gas, which is a costly endeavour. Moreover, this substitution only moderately reduces carbon intensity. This underscores the unique challenges Hungary faces in its energy transition, necessitating targeted and strategic approaches to achieve substantial carbon reductions effectively.

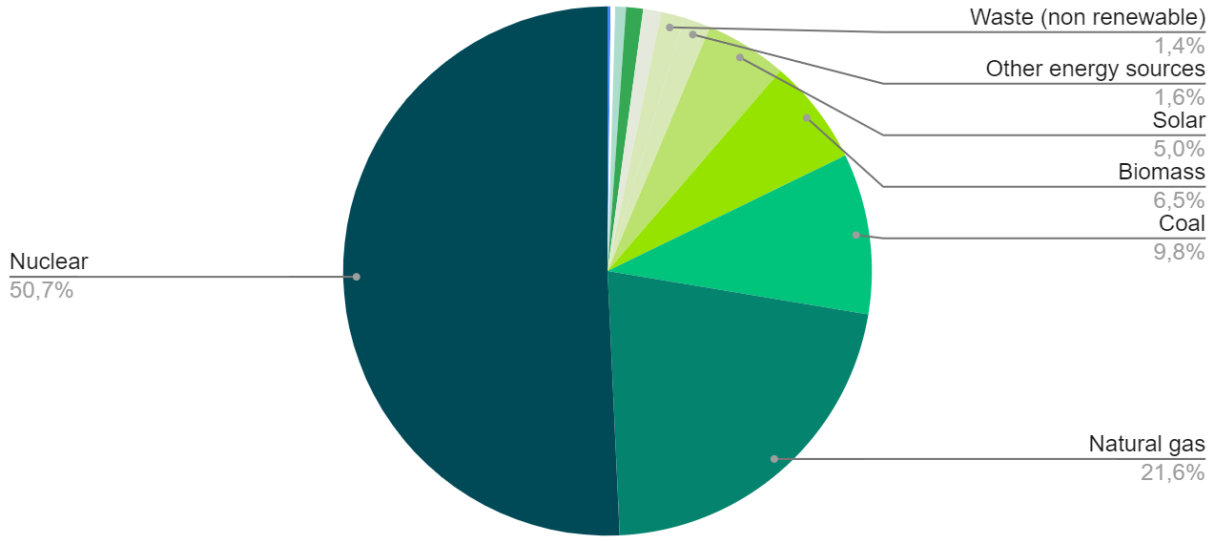


Figure 3: Ratio of emergy sources used for electricity generation, 2022[9]

The progress towards a greener economy in Hungary is hindered by policies that emphasise industrial growth and high level of subsidies to fossil fuel generation. Despite Hungary's limited own energy supplies, its strategy has primarily encouraged the establishment of energy-intensive industries, including significant battery assembly operations and automobile production.
The shift towards green energy, particularly in the realm of electrification, may necessitate vocational retraining for engineers in many sectors. There's a pressing need for more substantial initiatives in upskilling and re-skilling across industries facing decline or transformation, especially considering the minimal adult participation in training programs, including those working in sectors with high energy demands. The lack of green skills within the construction industry could further obstruct efforts to enhance building energy efficiency.

In Hungary electricity primarily is consumed by residential facilities. The practice of keeping residential energy prices low has reduced the motivation for households to use fossil fuels more sparingly. Hungary's energy and material consumption per unit of economic output exceeds the EU average. Unlike the trend observed in other EU nations, Hungary has not seen an improvement in resource efficiency over the past ten years. During the energy crisis of 2022-2023, a cap was introduced for subsidised household electricity and natural gas consumption, with subsidised prices applied below this cap and market prices applied above. This significant price increase led to a marked reduction in energy consumption. Additionally, these price changes, coupled with government grants aimed at promoting photovoltaic (PV) systems, resulted in a substantial increase in residential PV installations.

In Hungary, solar power has emerged as a dominant force within the renewable energy sector, reflecting a significant imbalance in the nation's energy production. This dominance has led Hungary to reach solar

[9] HEPURA, DATA OF THE HUNGARIAN ELECTRICITY SYSTEM 2022

energy saturation levels earlier than many Western European countries. Consequently, this rapid expansion has posed integration challenges within the national grid system. In 2023, solar energy accounted for 18.7 percent of all electricity produced in Hungary in total, increasingly contributing to renewable based electricity production growth from 21,4% in 2022 to 25,5% in 2023. This significant contribution has led to challenges within the grid system, occasionally (weekends, holidays etc.) resulting in moderate negative prices and overloads in periods when consumption is dropping. The rapid spread of weather-dependent producers primarily solar PV poses significant challenges for network operators and system controllers. Compared to fewer than three hundred instances the year before last, MAVIR experienced over one thousand fifteen-minute intervals with imbalances exceeding 400 megawatts last year. The number of hours with zero or negative prices also increased significantly on the domestic electricity exchange: there were a total of 96 such hours in 2023, more than in the previous ten years combined. One of the most crucial tasks now is the system integration of renewable energy sources and the creation of network flexibility. To address these challenges, the development of energy storage solutions and the enhancement of consumer flexibility will be critical. However, infrastructural investments on the grid have become increasingly difficult since network companies are undercapitalized and lack funds due to the reduced utility tariffs for households. Due to the poor state of the budget, DSOs did not receive the expected state development funds, leaving them reliant on EU funds, which are also unavailable. Consequently, significant improvements at the network level should not be anticipated.

The adoption of smart meters in Hungary is significantly lagging behind the EU average. By the end of 2021, 54% of homes in the European Union had smart meters installed. This figure increased by the end of 2022, with 13 member states achieving a penetration rate exceeding 80%. The European Union has set an ambitious goal to reach 100% coverage by 2030 (JRC SES). In stark contrast, Hungary's smart meter coverage stands at approximately 17%[10], based on an estimated 3.84 million households. This disparity underscores the need for accelerated efforts to enhance smart meter deployment in Hungary to align with broader EU targets.

Due to the reduced utility tariffs for households, investing to improve energy efficiency, smart home solutions or renewable sources is an investment that is unable to produce a return. Such installations are typically undertaken only when absolutely necessary, heavily subsidised, or driven by a strong personal commitment to innovation and technology. As a result, Hungarian and Eastern European innovation should focus on developing affordable and easily accessible products.

Hungary faces a complex **set of challenges** in its energy transition, including issues related to consumer engagement, regulatory barriers, societal attitudes, and the need for supportive policies and frameworks that enable a shift towards sustainable energy practices.

The Hungarian legal and political setting stands in contrast with the core idea of the decentralised renewable energy-based system, which aims at incentivizing and coordinating the demand-side as a flexible part of the electricity supply chain.[11] The policy of reduced utility costs and fixed, low tariffs is a

[10] https://www.eon.hu/hu/rolunk/sajtoszoba/sajtokozlemenyek/tobbe-nem-csonget-a-leolvaso.html
[11] Diestelmeier, L. (2019). Unlocking Flexibility with Law: developing a Legal Framework for Smart Electricity Systems. [Groningen]: Rijksuniversiteit Groningen.

political necessity that eliminates price risk and thus kills demand adaptation, at least in the residential sector. In the industrial and business sectors, things are better aligned.

The policy of reducing utility costs and maintaining fixed, low tariffs has been a political necessity, which, by eliminating price risk, stifles demand adaptation in the residential sector. This approach discourages households from adjusting their energy consumption in response to price signals, thus undermining efforts to promote energy efficiency and conservation. The low and fixed prices create a disincentive for residents to adopt energy-saving measures or invest in renewable energy sources, such as photovoltaic systems, despite the potential long-term benefits.

In contrast, the industrial and business sectors are better aligned with market dynamics, allowing for more efficient energy use and adaptation to price fluctuations. These sectors generally face fewer restrictions on pricing and benefit from more flexible tariff structures, which incentivize energy efficiency and the adoption of innovative technologies. As a result, the industrial and business sectors have been able to adapt more effectively to changing energy market conditions, maintaining a balance between consumption and cost. Digitalization is crucial for these sectors, as it enables the implementation of advanced energy management systems, the use of data analytics to optimise energy consumption, and the integration of smart grid solutions.

Hungary lacks abundant fossil fuel resources, leading to its reliance on imported fossil fuels and non-renewable energy sources, a situation that conflicts with climate policy goals in the European Union and beyond. The main forces behind Hungary's move towards an energy transition include the need for energy security and the influence of EU initiatives. Consequently, Hungary is considered to be behind in implementing effective climate policies. [12]

Despite incorporating EU consumer rights and renewable energy standards, Hungary significantly trails behind other European nations in renewable energy use, flexibility providers, community energy, and fostering a prosumer culture.

The Hungarian government lacks a comprehensive plan for the transition of its energy sector however multiple different strategies and funds collectively contribute to the sector’s transition.

- **National Recovery and Resilience Plan[13]** with an allocation of €1.2 BN for relevant reforms and investments to enhance its energy sector (43% of total budget) and €1.4 BN for sustainable green transport (44% of the total budget €5.8 BN) . Reforms include transforming electricity regulation, facilitating wind energy investments, simplifying renewable energy licensing procedures, and improving the transparency and predictability of network connections. Additionally, energy efficiency programs are being strengthened by requiring a 30% reduction in energy consumption for subsidised building renovations. Investments encompass several key initiatives, including grid development for renewable integration, support for residential solar systems and the

[12] Antal M (2019): How the regime hampered a transition to renewable electricity in Hungary, Environmental Innovation and Societal Transitions, 33:162-182,
[13] Hungarian Recovery and Resilience Plan and REPower chapters

electrification of heating systems combined with solar systems, and the installation of grid energy storage facilities at TSO, distributors, and energy market players. Additionally, the installation of smart meters across households and businesses is being promoted. The Plan includes a **RePowerEU** chapter which allocates €0.66 BN available non refundable funds directly to grid development. An additional €3.8 BN Focus is on accelerated deployment of renewables, expanded capacity of the grid, sustainable transport, increased energy efficiency, accelerated uptake of green skills. 12% of the Plan is dedicated to the digital transition.

- **Cohesion Policy** and **European Regional Development Fund** (ERDF) and **Just Transition Fund** that allocate funding through **The Environmental and Energy Efficiency Operational Program Plus Digital Renewal Operational Program Plus**.
- **Hungary's National Energy Strategy** aims to strengthen energy sovereignty, reduce utility costs, and decarbonize energy production through nuclear and renewable sources. Goals include promoting home-based renewable energy, smart meters, and electric mobility, aiming for 90% carbon-free electricity by 2030 with nuclear energy playing a key role.
- **National Energy and Climate Plan** (NECP) - In line with EU mandate.

Challenges for Hungarian's energy sector include:

- Hungary significantly trails behind other European nations in renewable energy use, flexibility providers, community energy, and fostering a prosumer culture due to strict regulations and a rigid institutional framework that hinder innovation and the adoption of new technologies in the energy sector.
- Low level of deployment of digital technologies (e.g. low penetration of smart metering). Despite available solutions, there is a significant lag in implementing smart technologies.
- The integration of weather dependent renewable generation poses serious challenges to the grid.
- Flexibility sources such as storage and new demand side balancing solutions need to be developed for better balance.
- Energy security by decreasing import (particularly during winter months, and given global geo-political tensions)
- Energy poverty and affordability (subsidised energy prices are available universally but the most vulnerable customers are, or not receiving in the extent they would need)
- Energy efficiency (e.g. large scale residential building insulation significantly would impact demand)
- Lack of implementing effective climate policies.
- Large energy companies, constrained by recent taxation and economic pressures, are hesitant to invest in new technologies, prioritising stability over innovation.

1.2 Functioning Innovation Ecosystems

1.2.1 Science, Research and Innovation Systems

Hungary, a "Moderate Innovator" according to the European Innovation Scoreboard 2023, showcases a nuanced landscape of innovation capabilities and performance. With an innovation index standing at 70.4% of the European Union average, Hungary's innovation ecosystem reflects both robust strengths and areas ripe for enhancement. The nation's performance, while showing positive growth, is increasing at a slower pace compared to the EU average, indicating a widening gap and underscoring the need for targeted policy interventions and strategic investments in innovation.[14]
According to Global Innovation Index 2023 Ranking,[15] Hungary positioned 35th globally. The country demonstrates a balanced performance between innovation inputs and outputs, with specific strengths in knowledge and technology outputs, as well as business sophistication. The dynamics of Hungary's innovation performance from 2016 to 2023 indicate both progress and setbacks in various indicators. While there have been significant gains in attracting foreign doctoral students and enhancing job mobility among highly qualified personnel, declines in government support for business R&D and sales of innovative products underscore the complexity of Hungary's innovation ecosystem.

In the following part we introduce the main national innovation strategies and funding program relevant for energy transition perspective. Eight national economic priorities have been selected for S3 strategy (see Fig. 3). These are the directions for the national economy that Hungary is focusing on in the implementation of smart specialisation. Focusing resources on priorities can strengthen competitiveness. In addition to the national economic priorities, two horizontal priorities have been selected. The horizontal priorities aim to develop skills and create a business environment for smart specialisation in sectors aligned with national economic priorities.

[14] https://ec.europa.eu/assets/rtd/eis/2023/ec_rtd_eis-country-profile-hu.pdf
[15] https://www.wipo.int/edocs/pubdocs/en/wipo-pub-2000-2023/hu.pdf

S3 PRIORITIES	Agriculture, food industry	Health	Digitisation of the economy	Creative industry
	Resource-efficient economy	Energy, Climate	Services	Cutting-edge technologies
	Public sector innovation		Cutting-edge technologies	
RDI STRATEGY	Knowledge production			
	Knowledge flow			
	Knowledge use			
SME STRATEGY	Strengthening the value-creating capacity of a high-growth business			
	Providing a predictable framework for the entire SME sector			
DIGITISATION STRATEGY	Improving the digital readiness of micro, small and medium-sized enterprises			
	Increasing the integration of digital technology in the economy			

Table 1: Hungarian S3 priorities

Within the framework of the János Neumann Program[16]Hungary has identified the focus areas and their selection methodology, on which the RDI (Research, Development, and Innovation) resources need to be concentrated in the upcoming period in order to strengthen the economic impact (outcome) of the RDI expenditures.

The program has outlined 3+1 key focus areas, emphasising the integration of green and circular economy principles. Aligned with the European Green Deal, it aims to foster a modern, competitive, and sustainable economy by advancing climate neutrality. This encompasses addressing climate change impacts, enhancing agricultural innovations and water management, boosting energy efficiency, speeding up the shift to clean energy, leveraging local energy sources, promoting sustainable and intelligent mobility, supporting alternative mobility solutions, and fostering innovations in energy storage and networks. The goal extends to various aspects of a sustainable environmental and bio-based economy, including waste management, cyclic and recycled technologies, and the development of new materials.

[16] János Neumann Program https://nkfih.gov.hu/hivatalrol/hivatal-kiadvanyai/neumann-janos-program

The Energy and Climate Priority in the RIS 2021-2027 Strategy[17] aims to support RDI activities related to nuclear energy and safety while promoting a low-carbon economy. The program focuses on scaling up innovative energy production, storage, and efficiency solutions, particularly in key industrial sectors. It also emphasises researching energy efficiency solutions for homes, ensuring the uninterrupted energy supply to critical infrastructures, and strengthening climate awareness through social innovations like skills development and smart solutions. The overarching goal is to reduce environmental impact and increase energy efficiency across various sectors.

The **National Energy Strategy by 2030** emphasises creating a regulatory environment that encourages innovative energy solutions to improve system balance and grid controllability while minimising network development costs. Key actions include incentivizing energy storage, integrating smart meters, and developing telecommunications networks and low-voltage control systems. The strategy also supports the formation of energy communities and proposes a "regulatory sandbox" for testing novel solutions. Additionally, it promotes the development of seasonal energy storage technologies using the natural gas network for methane, biogas, and hydrogen. These initiatives aim to enhance energy efficiency, reduce costs, and support the sustainable integration of renewable energy sources.

The national energy strategy also sets some specific goals for the energy transition, namely:

- To increase the share of domestically produced carbon-neutral electricity to 90% by 2030.
- To reach the installed photovoltaic capacity of 6000 MW by 2030 and of 12000 MW by 2040.
- To increase flexibility in the electricity sector by installing at least 1 million smart consumption meters.
- To stabilise the import ratio of electricity below 20% by 2040.
- To maintain the proportion of renewable energy usage within gross final energy consumption at a minimum of 21%.
- To decrease greenhouse gas emissions by at least 40% compared to 1990 levels

Funding for energy transition related projects are available from the following sources:

Széchényi Terv Plusz 2021-2027 (financed by EU fund such as ERDF, ESA+, CF, Just Transition Fund)

- **Digital Renewal Operational Program Plus**

The Digital Renewal Operational Program Plus aims to comprehensively target the improvement of Hungary's digital preparedness and enhance its competitiveness. The program has 4 priorities and priority 2 is directly related to energy transition with digital technologies. Priority number 2 - Green and High-Tech Transition aims to facilitate the spread of digital solutions and the use of data to transition towards a climate-neutral, circular, and more resilient economy. It underscores the role of digital technologies in achieving environmental sustainability, promoting the development and adoption of green technologies, and utilising data-driven insights to enhance efficiency and reduce environmental footprints. The FEAK data centre's funding is covered by these measures. Digital developments related to energy systems and

[17] https://nkfih.gov.hu/hivatalrol/nemzeti-intelligens/nemzeti-intelligens-szakosodasi-strategia-2021-2027

networks, energy management systems, and energy communities part of the program supports the following activities:

- Development of energy management systems utilising artificial intelligence, and IT decision support systems.
- Introduction of IT solutions that support the efficient use of energy.
- Transition of district heating systems to renewable sources.
- IT developments related to electrical systems (e.g., integration of electric charging stations, integration of energy producers based on weather-dependent renewable energy sources).
- IT developments affecting decentralised energy consumers, producers, and energy communities.

- **The Environmental and Energy Efficiency Operational Program Plus** provides support for addressing problems arising from the effects of climate change, such as issues with floods and internal waters, droughts, and the excessive use of our resources. The program has 5 priorities and one of them is the renewable energy economy. This priority covers the following measures:
  - Promotion of energy efficiency measures (for SMEs, residential buildings, public buildings, etc.).
  - Improvement of the efficiency of district heating and cooling systems.
  - Encouragement of renewable energies in community-level and power plant-level electricity production.
  - Transition of community heating and cooling to a renewable energy basis.
  - Development of smart energy systems, networks, and storage, targeting the flexibility of transmission and distribution networks.

However, many of these measures both in Digital Renewal Operational Program Plus and The Environmental and Energy Efficiency Operational Program Plus are not yet or only partially implemented, and it is critical to complete them by the end of the 2027 plan scope to realise their full potential.

Hungary's Recovery and Resilience Plan (RRP) and REPowerEU chapters[18]

The reforms and investments in Hungary's plan are helping it to become more sustainable, resilient and better prepared for the challenges and opportunities of the green transition and digital transition. Following Council approval of Hungary's plan on 15 December 2022, Hungary's recovery and resilience plan was updated on 8 December 2023 also to introduce a REPowerEU chapter. The value of the plan €10,430 m which consists of €6,512 m RRF Grants and €3,918 m RRF loans. 67.1% of the plan aims to support climate objectives and 29.1% of the plan will foster the digital transition.

Funding was provided by the European Commission's Next Generation EU program Recovery and Resilience Facility (RRF) instrument to counterbalance the economic and social impacts of the coronavirus pandemic, while also enhancing the economy's resilience, sustainability, and preparedness for the challenges and opportunities related to the green and digital transition. The F. Energy- green

[18] https://archive.palyazat.gov.hu/helyreallitasi-es-ellenallokepessegi-eszkoz-rrf

transition is one the 9 components of the program and energy is one of the top priorities of the Plan. The measures under the Energy (Green Transition) component will improve the resilience of electricity grids and energy supply by ensuring a resilient and secure electricity grid and integrating weather-dependent renewable energy sources.

The objective of the component:

- ensuring the regulatory conditions necessary to increase the share of renewable energy in the production of electricity and increasing related investments;
- creation of about 175 MW of new installed renewable energy production capacity with small household-scale power plants (<50 kW) in order to decarbonise the electricity production;
- the secure and flexible integration of the surplus renewable energy produced into the electricity grid; and
- providing access to electricity from renewable energy sources and modern heating solutions for households at risk of energy poverty.

The ultimate objective of the component is to reduce the annual GHG emissions of the energy sector by about 49,720 tonnes a year. The component contributes to the green transition, to economic recovery by stimulating investment, to increasing Hungary's energy independence by investing in renewable energy production at the level of the population, and to reducing energy poverty by creating energy independence also at the household level. Overall, the investment structure of the program is not focusing on fostering innovation rather it is focused on upgrading the current infrastructure and applying proven technologies.

REPowerEU chapters

In February 2023, the Council officially adopted an amending regulation aimed at incorporating REPowerEU chapters into the Recovery and Resilience Plan. Hungary's Recovery and Resilience Plan's REPowerEU chapter includes 14 reform measures and 14 investments. These chapters outline new reforms and investments starting from February 1, 2022, and/or expanded versions of already approved reforms and investments, complete with associated milestones and targets. The reforms and investments should particularly focus on:

- Developing energy infrastructure and facilities to meet immediate needs related to gas supply security, especially enabling diversification of supply for the benefit of the entire Union.
- Enhancing energy efficiency in buildings.
- Decarbonizing industry.
- Increasing the production and use of sustainable biomethane and hydrogen produced without fossil fuels.
- Raising the share of renewable energy and accelerating its deployment.
- Addressing energy poverty.
- Encouraging the reduction of energy demand.
- Tackling bottlenecks in internal and cross-border energy transmission and distribution, and supporting emission-free transport and related infrastructure, including rail.
- Supporting electricity storage.

Hungary's Recovery and Resilience Plan (RRP) and REPower EU is at risk due to ongoing disputes over EU payments, potentially jeopardising €5.9 billion from the RRF and an additional €4.6 billion from the RePowerEU chapter, totaling approximately HUF 4,095 billion. While the government has contracted HUF 1,060 billion and disbursed HUF 970 billion from the budget, this represents less than a quarter of the total program funds for the next two years. Due to incomplete fulfilment of 27 critical milestones related to transparency and reforms, Hungary has only accessed advance payments amounting to approximately €0.9 billion (HUF 380-400 billion). The remaining funds are pre-financed by the government, contingent on project completion. The necessity to pre-finance these programs exacerbate budgetary pressures, challenging the launch and sustainability of these initiatives. Addressing financial and regulatory hurdles is crucial for advancing Hungary's recovery and resilience objectives.

Type of investment in energy industry	RRF support request, net, million EUR
Classic and smart grid developments for transmission system operators and distributors	409,25
Support for residential solar systems and electrification of heating systems combined with solar systems	464,75
Installation of grid energy storage facilities at Mavir and distributors	145
Installation of grid energy storage facilities at energy market players	155
Installation of smart meters	55,75
Electricity grid development and digitalization in energy sector	1344,525
Supply Security Investments in Gas Storage Facilities	46,8
Green (Innovative and energy-Efficient) Solutions in manufacturing, industry, and technology)	2656,425
Hydrogen investments	251,425
Human resources in green economy	34,975
Geothermal energy utilisation	398,95
Public and residential energy efficiency investments	756,25
Support for sustainable transportation	682,575
Total	7401,675

Table 2: Estimated costs of planned investments RRF

The NRDI Office has set up a single funding system for the use of EU development funds for research, development and innovation (RDI) and domestic funds from the National Research, Development and Innovation (NRDI) Fund. The NRDI Fund, managed by the NRDI Office, is a separate public fund under the Public Finance Act that provides public support for research, development and innovation from domestic sources and is used exclusively for this purpose. The innovation contribution paid by businesses and the complementary contribution from the central budget provide a significant part of the NRDI Fund's resources. According to the RDI Act, the annual detailed programme strategy of the NRDI Fund, including both incentive and support programmes, is approved by the Government after consulting the National Science Policy Council. The NRDI fund focuses on applied research and innovation, the available annual grants are ca 147 bn HUF (2024) focusing on research and innovation activities in general, not specifically targeting energy related innovation and research activities.

The following table provides an overview of the national energy digitisation initiatives, programs and projects in Hungary.

NKFIH energy communities and flexibility actors project grant	The call published by the NRDIO for proposals for the implementation of a pilot project to support the development and operation of energy communities aims to support the implementation of operational and replicable pilot projects that can serve as examples for others, based on their institutional and operational experience, while identifying the challenges and barriers to realising their potential aggregation and active user behaviour, and proposing the necessary regulatory environment. Out of the 34 proposals received for a total budget of HUF 2 billion, 16 projects received a positive innovation support opinion during the pre-qualification peer review, out of which 13 proposals were submitted. In total, 7 projects received funding.
Project # 2020-1.1.2-PIACI-KFI-2020-00125, National Research, Development and Innovation Fund's 2020-1.1.2-PIACI-KFI-2020 Support Framework	The new research and development project initiated by the MET Group, Dunamenti Power Plant, and Navitasoft explores potential alternative methods for utilising renewable energy sources and examines how optimised automated algorithms can balance weather-dependent, intermittent electricity production. "Storing surplus electricity in batteries, which can provide power at night or during low wind conditions, is an ideal tool for smoothing out the fluctuations in renewable energy production. The challenge of intermittent production can be managed with data-driven, digital tools to meet the expectations of a carbon-neutral economy," said Péter Horváth, CEO of the Dunamenti Power Plant.
TwinEU, Direct EU Grant international project	TwinEU lays the groundwork for a digital twin of the entire European electric power system. With the efforts of 75 partners from 15 countries over 3 years and nearly 20 million euros in EU funding, the digital twin of the European electricity system is being developed within the TwinEU project. The Budapest University of Technology and Economics plays a key role in the consortium, responsible not only for the coordination of communications but also for demos involving Hungary. Few ventures within the EU's innovation framework, HorizonEurope, are as ambitious as the TwinEU project. Its goal is to develop the concept of a digital twin for the European electricity system. Digital twins will make the entire European electricity system more transparent, easier to control, and plan, thereby enhancing the efficiency of energy markets. This is crucial for achieving the EU's climate neutrality goals by 2050.
Danube InGRID	The project aims to facilitate the integration of increasing renewable-based electricity production into the network using smart technologies and ensure supply security by building and operating an intelligent grid, providing high-quality services to consumers in the Central and Eastern European region. The project

	employs smart technology for both domestic and cross-border infrastructure, creating a modern network infrastructure. It supports the integration of all users, including consumers, active consumers, and producers, to enable a higher number of renewable or distributed electricity producers to connect to the grid. The experience gained with smart technologies in Northwestern Hungary and Western Slovakia will benefit the affected electricity system users, distributors, and transmission system operators.
FEAK	The Independent Energy Data Centre Ltd. (FEAK) was established in June 2023 as a support institution of the Ministry of Energy, whose main task is to develop and apply solutions for increasing security of supply and the wider use of renewable energy sources in the electricity sector. The company is providing professional analytical background for the decisions of industry players, energy communities and other users by processing and optimising large volumes of energy consumer data with the support of artificial intelligence. FEAK is establishing a centralised energy management framework for public institutions to ensure the efficient use of energy by implementing the necessary improvements.
Békéscsaba Smart Grid	A complex energy programme is being implemented in Békéscsaba as part of the Modern Cities Programme. This includes the SMART GRID system, geothermal heat recovery, SMART street lighting, and the development of intelligent traffic control and environmentally friendly public transport systems. Objectives of the SMART GRID project are: - Increasing the share of renewable generation: to ensure that the electricity needs of the existing and planned buildings of the City of Békéscsaba and within this the Municipal Sports Centre are supplied as much as possible from renewable energy sources. - Optimising electricity costs: to reduce the municipality's expenditure on electricity purchases as much as possible. - Reduction of carbon dioxide emissions: to reduce the environmental impact (CO2 emissions) of the use of electricity in the Municipality of Békéscsaba to the greatest possible extent. Main technical characteristics of the completed SMART GRID I system: - 3 solar parks were built; - 2 solar parks over parking lots with a total of 2390 panels; - 1 ground-mounted solar park with 850 panels;

	- A battery energy storage was built with a capacity of 2,435 MWh, - a transformer station with concrete housing and - a smart grid centre was constructed; - nominal installed capacity: 1296 kWp.
EON FLEXON	EON Flex.ON is a complex programme supported by the Ministry of Energy involving several unique projects. Total cost of the investments to be made in the project are more than 5.3 million euros, with the Ministry of Energy co-funding 39%. The E.ON Flex.ON initiative aims to enhance the stability and resilience of the electricity network through innovative technologies. The project integrates advanced components like In-line Voltage Regulators (IVR) and On-load Tap Changer (OLTC) transformers to manage voltage fluctuations, particularly with the increased integration of renewable energy sources. Additionally, smart meters and IoT devices collect real-time data for dynamic grid management. Supported by the Hungarian Ministry of Innovation and Technology, this project exemplifies cost-effective, sustainable solutions for modern energy challenges. The Flex.ON programme serves as a model for other utilities looking to modernise their grids and improve service quality while supporting the transition to a more sustainable energy system.
Energy poverty and energy awareness	The project is supported by the Energy Poverty Advisory Hub (EPAH), which is an EU initiative operated by the European Commission at the request of the European Parliament. It serves as a network for stakeholder collaboration with the goal of tackling energy poverty and accelerating the just energy transition in European municipalities.
SMEnergy	Small and medium-sized enterprises face numerous risks and uncertainties when considering the introduction of renewable energy sources. Will the investment pay off? What options do they have, and how should they utilise them? The Interreg Danube SMEnergy project assists businesses in answering these questions. The project is supported by the Interreg Danube Transnational Programme and is implemented with the co-financing of the European Union and Hungary. Within the "Greener, low-carbon emitting Danube Region" priority of the Interreg Danube Region 2021-2027 program, it contributes to the objective 2.1, "Supporting the greening of the Danube Region's energy and transport sectors by enhancing the integration of renewable energy sources."
StoreMore	The StoreMore project, implemented in partnership with the leading city of Békéscsaba and partners from 10 Danube Region countries, aims to promote

	sustainable energy storage solutions in the Danube Region. The consortium aims to improve the efficiency of energy storage, reduce the environmental footprint and facilitate energy transition in the region. Subsequently, the development of an online modelling tool and an Artificial Intelligence-driven Renewable Energy Resource (RES) optimisation tool will be followed by the application of the latest technological innovations to provide solutions to these needs.
Hydrogen technologies	Renewable Energy National Laboratory project together with TTYE FORRÁSHÁZ Zrt. and the Hydrogen Center of the University of Pécs. The service provider signed a partnership agreement with the university to jointly explore the possibilities of cascading hydrogen technologies with the university's hydrogen economy department. For instance, the experts will evaluate the use of pure oxygen, obtained through water electrolysis, in wastewater treatment.
Support for the distribution of the Just Transition Fund resources **January 1, 2023 - August 31, 2024**	Energiaklub, as a partner, will implement the project "Support to the implementation of the Just Transition Fund in Hungary" between January 1, 2023, and August 31, 2024. This project supports the Prime Minister's Office and the Ministry of Energy in the allocation of financial resources from the Just Transition Fund. The project is realised within a consortium of 5 members, led by Trinomics based in the Netherlands, with the participation from Hungary including Energiaklub, the Regional Centre for Energy Policy Research (REKK), the University of Pécs, and the University of Miskolc.

Table 3: Digitisation Projects in Hungary

1.2.2 Business environment and Investment Climate

Economic Predictability	Hungary is recovering from a 2023 recession, with GDP expected to grow by 2.5% in 2024. Lower energy prices, weaker import demand, and tighter monetary policy have helped reduce high inflation from 25.9% in early 2023 to a projected 4.1% in 2024. Hungary's response to its deteriorating fiscal balance has been mainly based on potentially growth-harming public investment cuts and temporary windfall profit and sectoral taxes. These taxes were levied mainly on the energy, financial and retail sectors. Fiscal consolidation is necessary but may weigh on growth prospects, with the economy remaining exposed to energy price fluctuations and external risks However, Hungary faces vulnerabilities related to external and government financing needs, high budget deficits, and structural issues like low innovation and digitalization.
Financial market	The 2023 Hungary Country Report[19] highlights economic slowdown and inflation challenges, despite improvements in employment and poverty indicators. Investments spurred by fiscal and monetary policies have not boosted productivity growth, with funds shifting away from productivity-enhancing activities. Structural investments have not significantly improved labour productivity, signalling potential for growth. The country faces external balance issues, high inflation, and housing market concerns, exacerbated by Russia's war against Ukraine. Projections suggest subdued growth with continuing high inflation and unemployment risks, though a recovery is expected in 2024 with EU cohesion funds support. Structural reforms in education, innovation, and the business environment are necessary for sustainable growth. The Hungarian startup[20] ecosystem had its most prosperous year in funding, with local startups securing over €180M, a 60% increase from the previous year. This growth came from a few significant funding rounds, notably SEON's $94M Series B, nearly half of the total funds raised in 2022. A repeat of such a banner year seems unlikely as most local scale-ups are not expected to seek funding in the next 1-2 years. Government-backed funding has also slowed, with a 37% reduction in deal numbers over the past four years. Larger institutions in Hungary, such as MVM Group and Mol, are pursuing digital transformation to enhance operational efficiency and drive sustainable growth, allocating substantial budgets towards R&D initiatives. Strategic partnerships between incumbents and startups, like the E.ON Startup Accelerator program, are fostering innovation and the adoption of cutting-edge solutions. Significant portion of Hungarian startups focuses on web and mobile app development, indicating AI's permanence in the industry. Sixty percent are engaged in the B2B SaaS domain. Interest in web and mobile applications peaked at 66%, while consulting and customised solution providers declined by 16%, signalling a shift towards scalable models. Hardware and IoT solutions saw

[19] European Comission (2023) Country report

[20] Startup Hungary (2022)

	reduced prevalence due to investment and supply chain challenges during crises. AI continues to lead, with growth expected in GenAI, followed by Education, Fintech, and Analytics/BI, aligning with market trends.
Legal and Political Settings	Hungary's centralised energy governance allows the government to control the sector to secure affordable energy and ensure energy security, heavily relying on Russian hydrocarbons and nuclear technology. This model, coupled with historical geopolitical ties, has influenced Hungary's energy policies.[21] Post-2010 policies have not supported renewables, causing Hungary to lag in European renewable energy standings.[22] The centralised, state-owned energy infrastructure conflicts with the decentralised renewable energy model and EU climate policy goals. Hungary's energy transition is driven by external pressures and energy security concerns, rather than proactive climate policies. Climate policy actions aim to reach only the very next EU numerical targets without triggering incumbent and deep transformation for a longer-term sustainability process. The centralised ownership and politicised energy policies hinder consumer empowerment and the adoption of a prosumer culture. Hungary's approach involves intensive price regulation and public ownership, which fail to protect or empower consumers adequately. The simple copying of EU rules without adapting to Hungary's socio-economic context further complicates the energy transition. The current energy crisis highlights the need for supply security and diversified energy sources, focusing primarily on solar PVs and nuclear for stable base load. Technical challenges, such as grid improvements and large-scale storage, must be addressed to expand renewables. Demand-side policies and maintaining low country risk for financing are crucial for further progress.
Economic Predictability	Hungary is recovering from a 2023 recession, with GDP expected to grow by 2.5% in 2024. Lower energy prices, weaker import demand, and tighter monetary policy have helped reduce high inflation from 25.9% in early 2023 to a projected 4.1% in 2024. Hungary's response to its deteriorating fiscal balance has been mainly based on potentially growth-harming public investment cuts and temporary windfall profit and sectoral taxes. These taxes were levied mainly on the energy, financial and retail sectors. Fiscal consolidation is necessary but may weigh on growth prospects, with the economy remaining exposed to energy price fluctuations and external risks However, Hungary faces vulnerabilities related to external and government financing needs, high budget deficits, and structural issues like low innovation and digitalisation.

[21] John Szabo, Csaba Weiner, and Andra´s Deak (2021) Energy Governance in Hungary

[22] Miklós Antal (2019) How the regime hampered a transition to renewable electricity in Hungary

Financial market	The 2023 Hungary Country Report[23] highlights economic slowdown and inflation challenges, despite improvements in employment and poverty indicators. Investments spurred by fiscal and monetary policies have not boosted productivity growth, with funds shifting away from productivity-enhancing activities. Structural investments have not significantly improved labour productivity, signalling potential for growth. The country faces external balance issues, high inflation, and housing market concerns, exacerbated by Russia's war against Ukraine. Projections suggest subdued growth with continuing high inflation and unemployment risks, though a recovery is expected in 2024 with EU cohesion funds support. Structural reforms in education, innovation, and the business environment are necessary for sustainable growth. The Hungarian startup[24] ecosystem had its most prosperous year in funding, with local startups securing over €180M, a 60% increase from the previous year. This growth came from a few significant funding rounds, notably SEON's $94M Series B, nearly half of the total funds raised in 2022. A repeat of such a banner year seems unlikely as most local scale-ups are not expected to seek funding in the next 1-2 years. Government-backed funding has also slowed, with a 37% reduction in deal numbers over the past four years. Larger institutions in Hungary, such as MVM Group and Mol, are pursuing digital transformation to enhance operational efficiency and drive sustainable growth, allocating substantial budgets towards R&D initiatives. Strategic partnerships between incumbents and startups, like the E.ON Startup Accelerator program, are fostering innovation and the adoption of cutting-edge solutions. Significant portion of Hungarian startups focuses on web and mobile app development, indicating AI's permanence in the industry. Sixty percent are engaged in the B2B SaaS domain. Interest in web and mobile applications peaked at 66%, while consulting and customised solution providers declined by 16%, signalling a shift towards scalable models. Hardware and IoT solutions saw reduced prevalence due to investment and supply chain challenges during crises. AI continues to lead, with growth expected in GenAI, followed by Education, Fintech, and Analytics/BI, aligning with market trends.

Table 4: Business environment and Investment Climate in Hungary

[23] European Comission (2023) Country report

[24] Startup Hungary (2022)

1.2.3 Culture and Attitudes

Cultural and attitude barriers of energy transition in Hungary

Research hints[25] at the influence of **path dependencies**, where past decisions and practices in energy consumption and production continue to shape the current energy landscape. This includes practices that have encouraged energy consumption and discouraged efficiency, indicating a need for transformative policies that address these historical legacies. The price of energy has been a key political issue for decades of Hungarian energy policy[26]. Hungarian governments, since the communist are, have continuously taken a paternalistic approach by ensuring low prices, and subsidising prices to build political capital from this policy.

The politicisation of energy law and policy, alongside extensive price regulation and public ownership, fails to provide the legal and economic frameworks or empowerment necessary for consumer participation in the energy transition. This scenario highlights the limitations of merely adopting EU regulations without addressing the underlying political and socio-economic factors. Effective energy transition in Hungary requires comprehensive reforms beyond legal changes, encompassing socio-economic structures, institutional norms, and a holistic understanding of consumer behaviour influenced by various societal and environmental factors.

Energy democracy is not a frequently encountered term in Hungarian ecosystem mapping research. Energy independence self-determination is more frequently known, especially since the war and energy crises brought attention to the vulnerabilities of the Hungarian energy system (Russian gas, hectic pricing). The wider public is not aware about energy related problems and possibilities because of the aforementioned socio-political-cultural factors. However, the EU initiative to increase the volume of energy communities brings more attention to this topic, still large-scale capacity building activities as needed similarly to climate awareness campaigns to fill this gap.

Social enterprises in energy transition

In Hungary, **social enterprises** have existed since the late 1990s, and their number and diversity **have been increasing steadily**. **10.6% of social enterprises have set a goal to provide affordable and clean energy.** Over the past 20 years, several professional and business organisations have provided significant support for the development of social enterprises, recognizing their potential in addressing serious issues such as deep poverty or segregation. Social enterprise programs financed by domestic and EU funds have been coordinated in recent years by leading state organisations aiming to promote employment and business development. Alongside the growth in the number of social enterprises, there has been a dynamic increase, particularly in recent years, in the community of consultants and researchers focusing on social enterprises. Despite targeted investments and efforts in the field, the strengthening and development of the sector have fallen short of expectations.

[25] Cseres, KJ (2023) Varieties of Energy Transition: A Consumer-Focused Comparative Study in the Netherland and Hungary

[26] Szabó J, Weiner Cs, Deák A (2021) Energy governance in Hungary. In Knodt M, Kemmerzell J, (Eds.) Handbook of Energy Governance in Europe. Springer. 13:1-32.

Since 2011, the European Union has defined social enterprise as an organisation operating within the framework of the social economy, whose primary objective is to achieve social impact rather than generate profit for owners or shareholders. It mainly reinvests its profits to achieve its social objectives. Its operation is transparent, accountable, and innovative, involving its employees, clients, and other affected groups in its business activities.

Based on the experience of the Hungarian Coalition of Social Enterprises, **it is a problem in Hungary that the broad definition mentioned above has not spread**[27]. The definition, qualification, and detailed rules for financial and other support available to social enterprises in Hungary have always been determined based on the current values, goals, and main operational areas of the relevant state actors, ministries/background organisations, or other supporting entities. While job creation, the phasing out of public work schemes, and/or preserving the viability of rural areas are important policy objectives in themselves, they do not have to be primary or exclusive for social enterprises. **Due to the narrow focus, social enterprises in Hungary have not been able to develop in areas such as environmental sustainability or digital innovation, where their social utility could not be measured solely by employment indicators.** These often overriding policy objectives have so far strongly distorted the Hungarian social enterprise sector and hindered the spread and strengthening of the social enterprise model.

Social innovation and sustainable development supportive organisations/initiatives include:

- Hungarian Coalition of Social Enterprises (Társadalmi Vállalkozások Magyarországi Koalíciója)
- Transformátor
- National Society of Conservationists – Friends of the Earth Hungary (Magyar Természetvédők Szövetsége)

1.3 Ecosystem descriptions

According to the Nomenclature of Territorial Units for Statistics (NUTS2) level data from Eurostat and the Regional Innovation Scoreboard (RIS), a strong geographical concentration in the field of RDI can be observed in Hungary. Data shows significant disparities, especially between Budapest and the rest of the country, with Central Transdanubia progressing while Northern Hungary and Southern Transdanubia lag behind. Southern Transdanubia's underperformance is due to the lack of university-linked businesses. Northern Hungary's persistent lag is attributed to a lack of critical knowledge mass and few researchers. Increased regional innovation performance requires a critical mass of knowledge and collaboration between businesses and universities that needs to be improved (Source).

The following subchapters present regional ecosystems show the most collaborative efforts between the quadruple helix in the field of energy transition.

[27] European social enterprise monitor (2021-2022) Hungarian report

1.3.1 Regional Ecosystems

Budapest

Overview: Budapest is the leading region in Hungary regarding innovation performance, exceeding the national average by 46.6%. It plays a crucial role in the country's R&D, with significant contributions from both public and private sectors. Budapest, the capital region of Hungary, is recognized as a "Strong Innovator" with a Regional Innovation Index (RII) score of 101.4 in 2023, demonstrating its significant innovation performance. The city excels in various innovation metrics, including tertiary education, international scientific co-publications, and R&D expenditures in both the public and business sectors. Specifically, Budapest has a high level of tertiary education (61.1%), a substantial number of international scientific co-publications (2733), and notable R&D expenditures from both the public (0.54% of GDP) and business sectors (2.00% of GDP). The region also boasts a high concentration of ICT specialists and strong performance in innovation collaboration, particularly among SMEs. Despite these strengths, areas such as design applications and the sales of innovative products indicate room for improvement. Overall, Budapest's innovation ecosystem is robust and continues to drive forward, with a performance increase of 7.7% over time (Source).

The innovation ecosystem in Budapest is rich and diverse, including major universities, research institutions, large enterprises, and numerous SMEs. The presence of multinational companies further enriches the innovation landscape.

Knowledge Institutes: Key knowledge institutes include Eötvös Loránd University, Budapest University of Technology and Economics all of which are central to the region's innovation output. Also, many of the National Science Academy's research institutes are located in this region such as Centre for Energy Research (which is part of the HUN-REN Wigner Research Centre).

Business Actors: Prominent business actors in Budapest's innovation ecosystem include major tech companies, startups, and innovation-driven SMEs. Large corporations such as Ericsson, Nokia, and GE also have significant R&D operations here. There are functioning cluster organisations in the field of ICT (Alliance Infocommunication and Innovation Cluster, AgroIT Cluster). From the energy innovation sector Alteo is a key player and also facilitating actors like incubators and investors almost exclusively available in this region.

Collaborations: Budapest maintains strong connections with both national and international partners. Its central location facilitates collaboration with other Hungarian regions and neighbouring countries, enhancing its innovation capabilities.

Notable Projects:

- **FEAK**: The Independent Energy Data Centre Ltd. (FEAK) was established in June 2023 as a support institution of the Ministry of Energy, whose main task is to develop and apply solutions for increasing security of supply and the wider use of renewable energy sources in the electricity sector. The company is working together with IT companies to create the data centre and custom made AI algorithms.

- **TwinEU:** lays the groundwork for a digital twin of the entire European electric power system. Budapest University of Technology and Economics is a partner in it.
- **RECORD – Reimagining the EleCtric pOwer gRiD:**A new, more accurate loss estimation algorithm based on learning algorithms has been developed to address the weather-dependent challenges of predicting transmission network losses, leading to an improved procurement strategy
- **Alteo smart storage facility:** The 6-megawatt energy storage system at Zugló Heating Power Plant, owned by ALTEO, features a pioneering "smart" system that seamlessly integrates into ALTEO's control center and the national grid. Utilizing lithium-ion technology, this project, one of the first in Central and Eastern Europe, was completed between July 2017 and June 2019, with support from the National Research, Development and Innovation Office.

Pest

Overview: Pest County, surrounding Budapest, has shown a substantial increase in innovation performance, moving from 48.97% of the EU average in 2014 to 68.31% in 2021. It is categorised as an emerging+ innovator. Over time, Pest county's innovation performance has increased by 6.5%. The region shows strengths in areas such as tertiary education, with a participation rate of 36.3%, and above-average digital skills, where 22.2% of the population is proficient. However, Pest also faces challenges, particularly in international scientific co-publications and R&D expenditures in the public sector, which are below the national and EU averages. The region demonstrates a moderate level of innovative activity among SMEs, with a notable percentage engaging in collaborations. Overall, while Pest county has made progress in its innovation performance, there are areas requiring further development to enhance its position within the European innovation landscape (Source).

Knowledge Institutes: Prominent institutes include Szent István University in Gödöllő, which plays a significant role in agricultural and environmental research.

Business Actors: The region hosts a mix of manufacturing and service-oriented companies, with significant contributions from agricultural technology firms and industrial manufacturers. Chemical based battery related manufacturing (Toyo Ink, Samsung etc.) and smart metering manufacturing Wasion Holding (Gödöllő) have presence.

Collaborations: Pest maintains robust connections with Budapest and other neighbouring regions including cross-border regions through INTERREG to enhance cross-border cooperation.

Notable Projects:

- **Dunamenti Power Plant:** The power plant and Navitasoft as an IT company together explores potential alternative methods for utilising renewable energy sources and examines how optimised automated algorithms can balance weather-dependent, intermittent electricity production.
- **Green hydrogen plant**: MOL is building one of the largest capacity green hydrogen plants in Százhalombatta. The €22 million investment aims to produce 1,600 tons of green hydrogen

annually using electricity from renewable sources, thereby reducing carbon dioxide emissions by 25,000 tons.

Central Transdanubia

Overview: Central Transdanubia is classified as an "Emerging Innovator +" with a Regional Innovation Index (RII) score of 60.6 in 2023. The region has shown an innovation performance increase of 3.5% over time. Key strengths of Central Transdanubia include high levels of lifelong learning (6.9%) and substantial business R&D expenditures (1.60% of GDP). The region also benefits from a considerable proportion of employment in knowledge-intensive activities (20.9%) and demonstrates strong performance in public-private co-publications and product innovation among SMEs. However, there are areas for improvement, such as tertiary education participation and design applications. The region's structural differences, including a higher-than-average employment in manufacturing and lower-than-average employment in services, also play a role in shaping its innovation performance. Overall, Central Transdanubia's efforts in fostering innovation are reflected in its steady progress and emerging status within the European innovation landscape

Knowledge Institutes: The University of Pannonia in Veszprém is a key player, particularly in chemical engineering and environmental sciences.

Business Actors: Major industries include automotive, electronics, and chemical manufacturing, with companies like Volta Energy Solution and BorgWagner being significant contributors. There are functioning cluster organisations in the field of ICT and energy.

Collaborations: Central Transdanubian Regional Innovation Agency (CTRIA) is a key player in coordinating and promoting regional innovation processes. It manages national and international projects, fosters business consulting, encourages innovation, and facilitates technology transfer.

Notable Projects:

- **The Danube InGrid:** The project aims to integrate increasing renewable electricity production into the network using smart technologies and ensure supply security by building and operating an intelligent grid, providing high-quality services in Central and Eastern Europe. It employs smart technology for both domestic and cross-border infrastructure, supporting the integration of all users to enable more renewable and distributed electricity producers to connect to the grid.
- **EON Flexon:** The E.ON Flex.ON initiative aims to enhance the stability and resilience of the electricity network through innovative technologies.

Western Transdanubia

Overview: Western Transdanubia is also recognized as an "Emerging Innovator +" with a Regional Innovation Index (RII) score of 59.8 in 2023. The region has seen a 9% increase in innovation performance over time. West Transdanubia's strengths include tertiary education participation (28.8%), significant most-cited scientific publications (882.0), and above-average digital skills (21.8%). The region also shows solid performance in business R&D expenditures (0.63% of GDP) and innovative SME collaborations. However, areas like employed ICT specialists and design applications present opportunities for improvement. Structurally, the region has a higher than EU average employment in manufacturing and lower GDP per capita growth. Overall, West Transdanubia is making steady progress in innovation, reflecting its emerging status within the European innovation landscape.

Knowledge Institutes: The University of West Hungary and Széchenyi István University in Győr are key contributors to the region's research output. Audi Hungaria, one of the major industrial players in Győr, collaborates with Széchenyi István University to advance R&D in automotive technologies

Business Actors: The automotive industry is particularly strong, with companies like Audi and other suppliers driving innovation.

Collaborations: The Győr Innovation Park fosters collaboration between Széchenyi István University and several leading companies. It emphasises intelligent mobility, digital development, and green transition projects. Audi Hungaria collaborates closely with the university to develop hardware and software for future vehicles, and the park also hosts the Green Traffic Cloud project and other digital and telecommunications technology initiatives. Initiatives in Zalaegerszeg include projects focused on green transport solutions, leveraging local expertise and partnerships with educational institutions and the private sector. These projects aim to enhance sustainable mobility and integrate digital technologies into transport infrastructure.

Pannon Business Network plays a vital role in connecting SMEs with research institutions and larger corporations to foster innovation. This network facilitates knowledge exchange and collaborative projects that drive technological advancements and economic growth.

The region maintains strong cross-border connections with Austria and Slovakia, enhancing its innovation ecosystem.

Notable Projects:

- **NN PWER CUBE**: The NN Power Cube is a modular unit combining technical features and smart solutions, which is able to provide a complete, uninterrupted power supply for a given system, building or part of a building, either stand-alone (installed in a container) or integrated into a building. The system is able to combine grid electricity, electricity generated by solar panels and electricity generated by an aggregator to ensure a consistent operation. The system uses

primarily green energy for operation and only buys grid electricity when the solar panels no longer produce enough to ensure uninterrupted operation[28].

- **Zala Zone:** The ZalaZONE Park is the dynamically improving industrial district directly next to the Automotive Proving Grounds, which provides a quite frequented location to those interested in the automotive industry and industrial business. The focal point of the park is to provide a competitive environment for proving, validation and the advancement of modern technology, research and development.

Southern Great Plain

Overview: Southern Great Plain (Dél-Alföld, HU33) is classified as an "Emerging Innovator +" with a Regional Innovation Index (RII) score of 59.4 in 2023. The region has shown a moderate improvement in its innovation performance over time, with an increase of 4.9%. Key strengths of the Southern Great Plain include strong performance in public-private co-publications (264.5), high levels of trademark applications (3.61), and substantial R&D expenditures in both the public (0.47% of GDP) and business sectors (0.77% of GDP). Additionally, the region demonstrates robust digital skills (20.6%) and a significant number of international scientific co-publications (848). However, there are areas for improvement, such as tertiary education participation and the number of employed ICT specialists. Structurally, the region has a higher-than-average employment in agriculture and mining, coupled with lower GDP per capita. Overall, Southern Great Plain's steady progress in fostering innovation reflects its emerging status within the European innovation landscape.

Knowledge Institutes: The University of Szeged is a key player, particularly in life sciences and environmental research. Also, the Extreme Light Infrastructure (ELI ALPS) laser infrastructure and research institute is located in Szeged. ELI creates a research toolkit for international users that is unparalleled not only in the region but also globally, thereby ensuring the country's innovation competitiveness. In collaboration with its partner network and cooperating higher education institutions, ELI contributes to strengthening Hungary's labour market and knowledge-based society.

Business Actors: Key industries include car manufacturing, life sciences, biotechnology and laser technology.

Regional Connections: The Software Industry Innovation Pole Cluster, built on the cooperation of industrial partners of the University of Szeged and the operation of the e-Szeged consortium, represents significant innovation potential in its five focus areas. These innovation focus areas (platforms) are: software quality, applications of embedded and mobile systems, applications of language and speech technology, healthcare applications, and industry-specific administrative solutions.

Daimler, through its Mercedes-Benz subsidiary, has made significant investments in Kecskemét, which have substantially boosted R&D opportunities at Kecskemét College. The collaboration between Mercedes-Benz and Kecskemét College has opened new avenues for R&D activities, particularly in the

[28] http://okosvaros.lechnerkozpont.hu/en/node/1221
https://nnpower.hu/nn-power-cube/

fields of digitalization and sustainable energy. This partnership aims to leverage the latest technological advancements to foster innovation and enhance the competitiveness of the Hungarian automotive industry.

Among the European Territorial Cooperation programs, the Hungarian-Serbian and Hungarian-Romanian cross-border cooperation programs hold particular significance in the Southern Great Plain region

Notable Projects:

- **Hydrogen production:** Researchers from Szeged Universtity in collaboration with ThalesNanoEnergy Zrt. and W7Energy LLC, developed a pioneering electrolyzer technology that uses only water and carbon dioxide. Supported by the Hungarian government and the EU's H2020 program, this innovation is the first to exceed 1 ampere per square centimetre in carbon monoxide production, offering a novel solution for storing electrical energy as gas.
- **StoreMore:** The project in partnership with Békéscsaba and partners from 10 Danube Region countries, aims to promote sustainable energy storage solutions using an online modelling tool and an AI-driven Renewable Energy Resource optimization tool, enhancing efficiency and facilitating energy transition.
- **Békéscsaba SMART Grid:** A complex energy programme is being implemented in Békéscsaba as part of the Modern Cities Programme. This includes the SMART GRID system, geothermal heat recovery, SMART street lighting, and the development of intelligent traffic control and environmentally friendly public transport systems

Geothermal District Heating System: Szeged has implemented the largest geothermal heating system in the EU, significantly reducing the city's reliance on natural gas and lowering CO2 emissions. This extensive network, consisting of 27 wells, 16 heating plants, and 250 kilometres of distribution pipes, provides clean, renewable energy to over 28,000 households and 400 public buildings.

1.3.2 Energy Ecosystems

Overview:

Sector innovation ecosystems in the energy sector in Hungary are formed around a handful of key national players that represent the industry (MAVIR, MVM, EON, ALTEO), smaller private enterprises, and academic actors (Budapest University Of Technology And Economics, HUN-REN Center for Energy Research). Also in terms of social innovation there are NGOs working on frameworks and pilots for decentralised and sustainable energy solutions, energy cooperatives, communities, financial instruments etc. (MTVSZ, Energia Klub, Transformátor).

Ecosystem Actors:

- Business actors:
    - Transmission System Operator (TSO): MAVIR
    - Electricity and gas wholesaler: MVM,
    - Distributors (DSO): EON, MVM, OPUS

    - Innovative companies: ALTEO, Dunamenti Erőmű, Thales Nano, Navitasoft
    - Startups: Enerhash, Smart Capacit, HeatVentors
- Incubators and Accelerators: EIT Inno Energy Green Brothers, MVM Edison, MVM Smart Future Lab
- Knowledge institutions: Budapest University Of Technology And Economics, Budapest University Of Technology And Economics (Smart Power Lab, Faster Research Group, High-Voltage Lab,, Zero Carbon Center), HUN-REN Center for Energy Research, HUN-REN Wigner Research Centre for Physics, Óbuda University, Eötvös Loránd University. Regional Energy Research Center providing market and regulatory analysis.
- Regulatory bodies: Ministry of Energy, Hungarian Energy and Public Utility Regulatory Authority (HEPURA)
- Civil society: Energy Club, GreenDependent Institute, Hungarian Energy Efficiency Institute, Transformátor
- Other stakeholder associations: Hungarian Energy Communities and Flexibility Service Providers Association, Block Chain Coalition

Relations and Interconnections:

These actors collaborate through programs and research based experimental projects aimed at advancing energy technologies, such as smart grids, grid stability, cybersecurity, smart storage and renewable energy integration.

Innovations Produced:

Innovations include e-mobility related charger innovations and chemical and alternative energy storage solutions, AI based software solutions, conductor materials and research on green hydrogen.

Cases:

- **Energy Storage and Smart Systems:**
  - **ALTEO**: 6-megawatt energy storage system at Zugló Heating Power Plant, featuring a pioneering "smart" system.
  - **Enerhash Ltd**.– Energy Management Systems: See the detailed description in the case study
  - **ElevenEs:** an industrial spin-off of the multinational Al Pack Group, which specialises in aluminium processing and has been operating on the packaging market for 25 years, has developed its own technology to produce lithium-iron-phosphate batteries that are more sustainable and efficient.
  - **StoreMore:** aims to promote sustainable energy storage solutions using an online modelling tool and an AI-driven Renewable Energy Resource optimization tool, enhancing efficiency and facilitating energy transition.
- **Energy management softwares:**
  - **Flexible aggregator platform**: Development and optimization of a flexible aggregator platform in the electricity system at Dunamenti Power Plant.
- **Green Hydrogen:**
  - **Green Hydrogen Production:** Developed an energy-efficient electrolyzer technology that uses only water and carbon dioxide, surpassing 1 ampere per square centimetre current density.
  - **Green Hydrogen Power Plant:** MOL is building one of the largest capacity (CEE region) green hydrogen plants in Százhalombatta.
- **Smart Grid Projects:**
  - **E.ON Flex.ON**
  - **Békéscsaba Smart Grid**
  - **Danube InGrid**
- **Social innovation:**
  - **Kazán Community House**: See the detailed description in the case study
  - **Tranformátor:** non profit agency providing support for energy communities from administration, till finance and business models, also providing advocacy in policy field to remove regulatory barriers which hinder the spread of energy communities

Challenges & conclusion

Over the past decade, Hungary has seen significant progress in the installation of renewable energy systems, becoming a viable option for investors, businesses, institutions, and the general public. Despite the challenges faced during this relatively short period, technological advancements have often outpaced their implementation. Moreover, the regulatory environment and public perception have undergone rapid changes, sometimes hindering smooth adaptation.

The energy sector is characterised by a rigid institutional framework and strict regulations, creating a challenging environment for innovation. Large industry players prioritise stability, making them risk-averse

and less likely to invest in new technologies. Additionally, there is often low motivation for entrepreneurship and collaboration within traditional energy companies, and a lack of access to innovative ideas and expertise necessary for managing highly innovative projects.

Industry-specific barriers include the need for complementary resources such as capital, infrastructure, and expertise related to grid operations. Traditional energy companies, which could provide these resources, are often not inclined to invest in disruptive technologies due to their focus on stability and short-term performance. Large companies in general due to recent taxation practices and the economic recession became even more risk averse when it came to investments in innovative technologies.

Technology-specific barriers include efficiency challenges at both the sector and technology levels. At the sector level, high electricity input requirements and the rapid deployment of renewable energy sources (RES) present challenges. Increasing the pace of RES deployment can lead to higher maintenance costs for transmission system operators (TSOs).

Legal and regulatory barriers are not in favour of innovation in the energy sector, there are no effectively functioning regulatory sandbox and there are no field labs to test out solutions.

Hungary's strategic goals for energy transition and innovation, as outlined in the RIS 2021-2027 Strategy and National Energy Strategy by 2030 align well with several ongoing projects and innovations in the energy ecosystem. However, most of these projects are not at a scale that would cause significant advancement; many are small-scale and pilot projects. RRF plan with the REPower EU chapters contains significant investments for the upcoming year on the domain of digitalisation in the energy sector, but these investments yet are merely plans and not so much has been realised from it due to the disputes around the funding.

Additionally, the adoption of existing proven technologies is lagging, hindering the green transition in terms of energy production and usage. Significant disparities exist in achieving these goals due to heavy reliance on energy imports, slow adoption of smart technologies, regulatory and financial barriers, and inadequate workforce development.

1.3.3 Programme/Project based Ecosystems

Throughout the course of our research activities, no evidence was detected of a lasting ecosystem in Hungary that is based on programs or projects. Despite extensive investigation, such a sustainable and enduring framework was not observed.

2. The Netherlands

Country profile[29]:
Region: EUR
Income: High
Population (mn): 17.6
GDP, PPP$ (bn): 1,226.7
GDP per capita, PPP$: 69,715
Global Innovation Index, rank: 7
Total energy consumption per capita, kWh[30]: 56,000

2.1 Energy Systems State and Challenges

Introduction

The purpose of this chapter is to provide a factual overview of the Netherlands' path to transforming its energy system to be predominantly dependent on renewables. To achieve this, significant efforts are needed on the digitalisation and deep tech embedment front. In the following paragraphs, we describe the current state of the energy system, the most important policies, challenges that make digitalisation, deep tech embedment, and decentralisation necessary, and an overview of most important players, projects and regional initiatives. In a separate recommendation chapter, we go into necessary actions to be taken.

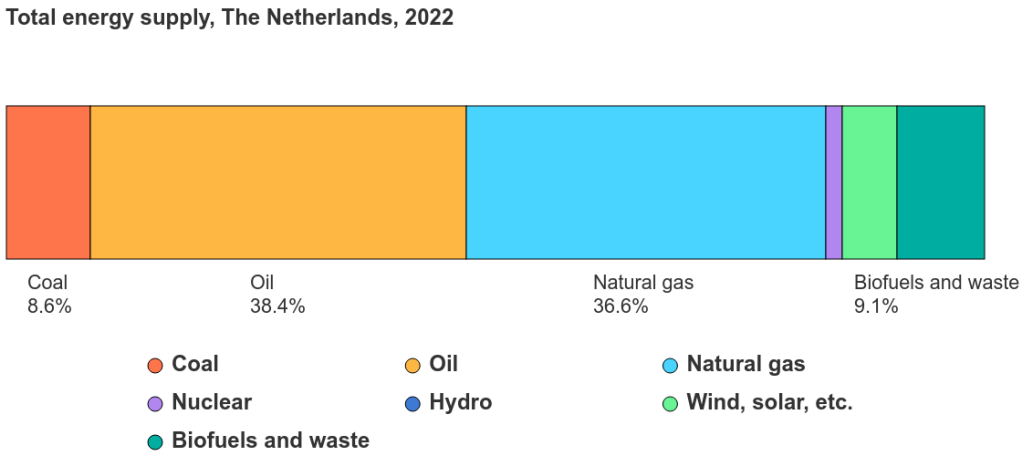
Total Energy Supply (TES)

The total energy supply (TES) in 2022 equaled 63.73 Mtoe and consisted mainly of oil (38.4% or 24.51 Mtoe) and natural gas (36.6% or 23.34 Mtoe), as well as coal (8.6% or 5.51 Mtoe), biofuels and waste (9.1% or 5.77 Mtoe), and other renewable resources such as wind and solar (5.55% or 3.52 Mtoe), and nuclear

[29] https://www.wipo.int/edocs/pubdocs/en/wipo-pub-2000-2023-en-main-report-global-innovation-index-2023-16th-edition.pdf
[30] https://www.iea.org/countries/the-netherlands/energy-mix

(1.7% or 1.08 Mtoe). It is notable that TES is fossil fuel-dominated; however, TES is not the total electricity generated. The latter is a fraction of TES and is around 50% renewable-based.

Final energy consumption in 2021, corrected for temperature variations, was 43 Mtoe, meaning the Netherlands solely used 67.4% of the TES. That means about 32.6% of the total energy generated was lost in conversion (predominantly as waste heat) and during transportation. This highlights the need for



increasing energy efficiency. The focus on getting final consumption down instead of the primary energy input results in a lack of focus on better use of energy. The Netherlands' final energy consumption per capita is high (56,000 kWh) due to the fact that the Netherlands is relatively industrialised compared to its size and population.

Total Electricity Generation (TEG)

TEG is a fraction of TES, only accounting for the total electricity produced in a country in a year. The Netherlands performs very well in TEG, with about 50% of TEG originating from renewables. Geographically, the offshore wind farms in the North Sea play a significant role in the renewable energy infrastructure of the Netherlands. It is notable that residential solar has become very popular, with 1 out of 3 Dutch households having their own panels. Onshore wind farms and solar parks are also expanding. Moreover, the Netherlands has one nuclear power plant, Borssele, which contributes a small percentage to the total energy supply. This is set to grow to five power plants, as announced by the government in May 2024.

State of the Energy Sector

The Transition to Renewables: Challenges and Changes

The energy transition is more than just switching from coal, oil, and gas to wind, biomass, geothermal and solar. The new energy sources are decentralised and less predictable and/or manageable. The increasing adoption of decentralised renewables is putting stress on the low voltage grid, even leading to power quality issues. At the same time, demand is using bigger volumes at specific times which has an adverse effect. We observe in the Netherlands the outcomes of transitioning to a more renewable energy system without using energy planning, monitoring local energy flows to manage demand and storage. Although the era of the unlimited grid capacity (the copper plate) is unofficially over, many market players still want to act as if we could get it back by massively investing in more grid capacity. This is understandable, as their knowledge and business models fit in the old system. We are at a point where parties will slowly accept that trying to hold on to the old will not work, and they will start seeking smarter solutions. The EU action plan for digitalisation of the energy sector has listed the necessary actions, but knowledge of this plan is not widespread, and implementation has yet to start.

The Netherlands shows that governments and grid operators for a large part have been, and continue to be, surprised by grid congestion. First it was the rapid growth of solar panels on the production side, but now we also see problems in parts of the Netherlands due to electrification of heat systems, industry, and mobility. For 3 regions (GFU Gelderland, Flevoland, Utrecht) a complete stop on grid connections has been announced, hindering businesses, schools and new houses to be built. Some still deny the problems, claiming it is only temporary, while scenarios on electrification and grid needs still overlook many local electrification plans, leading to gaps in understanding future requirements. For example, the infrastructure for alternative fuels obligation (AFIR) will have a big impact on the grid by 2025, but the needed charging stations are not included in 90%-100% of the scenarios. Therefore, compliance is becoming increasingly unrealistic, similar to many other climate ambitions. Simulation models and digital twins, which could provide stakeholders with the wanted overview on where problems may arise and how they can influence the outcomes through better energy planning and energy management, are hindered by lack of access to data. This is a result of the perception of data sharing rules and regulations that do not differentiate between types and reasons for the use of data, and the organisation of datasets in such a way that most sets include (unnecessary) privacy sensitive information.

Due to the congestion problems and the high energy prices of 2023 actions have been taken. Universities and communities in experimental areas are exploring real energy sharing with various ownership models. Additionally, grid congestion issues motivated many businesses to form energy hubs, leading to the start, at various stages of development, of 140 energy hubs that intend to implement real-time monitoring by energy management systems that control production, demand, storage and/or conversion. These new approaches attract many new innovative players and startups offering solutions to facilitate every step of innovation needed. This energyhub - energy community approach is quickly spreading to new areas, where net neutrality is a condition for access to energy, like new construction and housing renovation areas. These initiatives are essential, and it is notable that the necessary change is driven by local bottom-up initiatives, trying to use sensible and smart technologies that are available; while facing obstacles from the system that hinders these initiatives with strict and limiting

rules and regulation and a lack of or adverse incentives, though the new energy law will to some extend improve this. The frustration, among companies unable to expand or comply with environmental regulations (ETS, electrifying transport) and citizens who have bought houses but cannot live in them due to lack of grid access, is sometimes tangible but it has not yet been enough to drive systemic change. Local governments, however, understand these needs and lobby for new rules and access to data. This would allow them to start simulating (using digital twins) the future needs for access to the grid and availability of local energy sources. At the same time, DSOs are investing massively in (research on) smart grids and working on digitalising of medium- and low-voltage systems. The recently approved code of conduct for using smart metering data in the Netherlands can be seen as a best practice for the rest of Europe. The biggest step now is to align all parties to work in the same direction, which, not coincidentally, would be the direction of the EU action plan for digitalisation of the energy system.

Current Challenges

Transition Away from Natural Gas

The Netherlands faces challenges in moving away from its dependence on natural gas, especially as this transition means that households, companies and all sorts of building owners have to decide on other sources of heating and cooking. Local governments have made local heating plans with mixed input from citizens to choose which areas will transfer to heat grids, heat pumps or new gasses. The outrole of these plans proves to be much more difficult than envisioned as rules, regulations and incentives still hinder easy transition and the market propositions for these new carriers are not yet appealing. The implementation of the new energy law should alleviate some of the hindrance, though front runners are critical about for example the type of data that can be shared and the conditions. The lack of decision regarding the heat transition hinders grid planning, as the extent of local electrification remains unknown. Using digital twins to explore multiple scenarios, including smarter and more efficient system integrated solutions, could help governments and building owners to better understand their options and tailor them to local conditions.

Energy Poverty

Energy poverty impacts an estimated 750,000 households in the Netherlands, representing between 9-12% of homes. A household is defined to be in energy poverty when they have to spend more than 10% of their income on energy bills. This is a well-quantified and different energy poverty definition from that of the WHO, which defines it as “lack of access to modern, efficient and clean cooking facilities” and “lack of access to a reliable source of electricity”. This challenge persists despite the country's general affluence. These households struggle to afford their monthly energy bills, a situation exacerbated by inefficient housing (houses that aren’t energy efficient).

Grid Congestion and Grid Enhancement Issues

Grid congestion presents a significant challenge, influenced by both supply and demand factors. On the demand side, the electrification of various residential energy systems such as transportation (electric

vehicles) and heating (heat pumps) often leads to demand spikes between 17:00 and 19:00, putting substantial pressure on the grid infrastructure. Conversely, on the supply side, intermittent energy sources like solar and wind contribute to peaks between 11:00 and 13:00 when energy supply surpasses demand. Historically, there were never any problems with possibly reaching the boundaries of the medium and low level grid, so the maximum limits of components were not properly registered. It simply wasn't necessary.

Currently, we are unaware of the capacity of many parts of the grid. As of February 2024, the urgency of this issue is underscored by the fact that over 9,400 companies are on a waiting list to connect to the grid. This list grows longer every day as 2/3 of business parks are already in congestion zones. Entrepreneurs in these areas face waiting times of six to ten years. Upgrading the grid to handle 2-2.5 times the current load and variability would require an investment of around 200-250 billion euros. Meanwhile, the increase in electrification predicts a need of between 5 and 7 times the current use in 2050, making relying solely on grid reinforcements an impractical and extremely expensive option. The costs of grid development were also seriously miscalculated, as in 2020, the estimated amount was only 40 billion euros. This has increased to 5-6x that amount, to 200-250 billion estimated. TenneT alone aims to spend 160 billion on grid enhancement. All these costs would lead to higher tariffs for end users which is not widely acknowledged yet. Research in the UK has shown that digitalisation can substantially lower the need for expanding grids and with that the costs, which is now also being researched in the Netherlands.

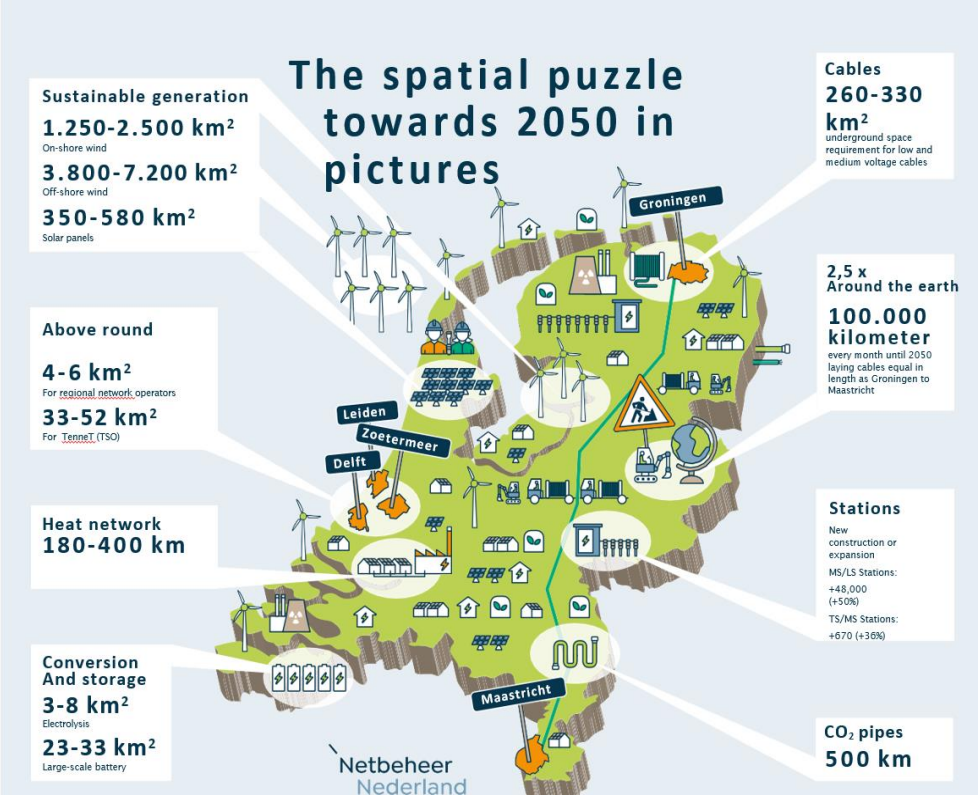


Figure 4: The spatial puzzle towards 2050 in pictures in the Netherlands

However, the problem of expanding the grid is not just the cost. The figure above shows the substantial spatial requirements for sustainable developments such as wind turbines, heat networks, storage facilities, and grid enhancements. Space is also being claimed for other issues such as housing shortages and water management challenges. An example of this battle is the recent request of local governments to place all high-voltage connections underground rather overhead. This would make the whole undertaking 10 times more expensive and considerably more time-consuming. Not to forget that the distribution network operators will need additional 18,000 technically skilled personnel to execute the current plans.

Public acceptance of energy initiatives, like wind farms, solar parks and high-voltage stations is a challenge. For example, social attitudes focused on individual benefits and concerns about visual impact, noise, and perceived health risks can delay or prevent renewable energy projects.

The Role of Hydrogen and the Need for More Research into Emissions Monitoring and Prevention
Hydrogen (H2), while a promising alternative energy source, also poses environmental risks if not managed correctly. It acts as an indirect greenhouse gas and can exacerbate climate change when it leaks into the atmosphere. Current detection technology in the Netherlands, as well as in other countries, is equipped to identify major hydrogen leaks in real-time that could lead to explosions. These systems can detect hydrogen concentrations at the level of parts per million, which is sufficient for identifying substantial leaks. However, they lack the sensitivity required to detect smaller leaks—those that emit hydrogen at a concentration of parts per billion. Until now, the Netherlands could only measure this by bringing air samples to a lab. As of May 2024, a new technology, already in use in the USA, is being tested in the Netherlands that allows real-time measurement of parts per billion. These smaller, yet persistent leaks contribute to environmental pollution and require more advanced detection capabilities to manage effectively. More in general, H2 has a large potential as it's a good energy carrier, that can be made from renewable electricity via electrolysis (green H2), that could help in balancing the grid significantly.

A System in Transition - Policy and Regulatory Framework

Overall, the transition from fossil fuels to renewable energy sources like wind and solar represents a monumental shift in the energy landscape. The current problems can be seen as transition failures as opposed to market failures. (ESB-artikel 'Beleidseconomen moeten weten wat transitiefalen is' - Wimar Bolhuis) It is imminent that the Netherlands will move to significant changes in the current rules, regulations and roles. At present, the old and new systems clash in the energy sector, leading to what is described as the “chaos” state in the DRIFT model.[31] Many existing players rely on rules that favour centralised energy production and incentives that they are used to for their business model. The upcoming demand by local governments, end-users and new players for rules that favour a decentralised system with for example new tariff models favouring certain net behaviour and allowing

[31] Hebinck, A., Diercks, G., von Wirth, T. et al. An actionable understanding of societal transitions: the X-curve framework. Sustain Sci 17, 1009–1021 (2022). https://doi.org/10.1007/s11625-021-01084-w

energy sharing has created a turbulent environment and heated discussions in consultations around new policies.

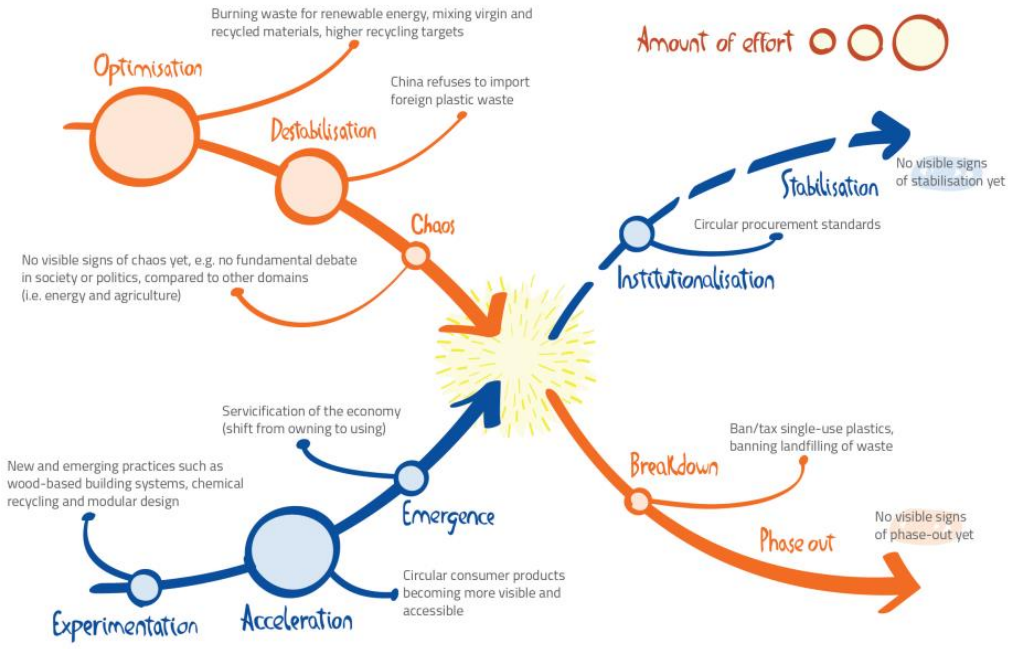


Figure 5: X-Curve example, The transition to a circular economy in the Netherlands (Bode et al, 2019)

This transition is not only technical; it's a social shift where energy will become a different kind of product in the future: more local, with increased ownership, more efficient use, and, hopefully, less expensive. As stated, the EU has a comprehensive vision for the digitalisation of the energy sector, focusing on enhancing efficiency and integrating advanced technologies. The Netherlands has taken initial steps with the Ministry of Economic Affairs and Climate Policy towards local energy systems, while NP RES and Topsector Energie are working on implementation. However, digitalisation remains within a relatively small community and is not yet widely recognised for its potential impact.

Despite the recent changes from May 15, 2024, according to the new EU regulatory agenda and vision, that reduced some of the regulatory bottlenecks, the Netherlands still faces some legal obstacles that can slow down a bit, the realisation of climate goals[32]. The current policy framework does not fit renewables, as it is optimised for fossil fuels, especially for natural gas. Electricity prices in the market are often set by the marginal cost of production. This means that the price for electricity is determined by the cost to produce the last unit of power needed to meet demand. In Europe, gas-fired power plants often set this marginal price because they are typically used to respond to fluctuations in demand due to their ability to quickly ramp up or down. The regulatory framework in the Netherlands, like most countries, has traditionally been more oriented towards fossil fuels, including natural gas. This framework may not fully

[32] This paragraph was updated last in May 2024 and therefore does not reflect the impact of the new energy law. At first sight, this law regulates peer-to-peer energy sharing and micro-suppliers and return delivery of energy. It is unclear if this will provide enough space for the transition in practice.

accommodate the integration and pricing dynamics of renewable energy sources, which can lead to inefficiencies and discrepancies in energy pricing, particularly in situations where global events affect fossil fuel markets. In 2022, this issue ended up making 4-5x more profit to owners of solar and wind parks, as their cost of production did not increase. This scenario highlights the need for regulatory adjustments that better reflect the growing role of renewable energy sources in the energy mix, ensuring more stable and predictable energy pricing. This transformation involves not just technological changes but also shifts in responsibilities, regulations and changing roles. This newer, decentralised model makes the role of centralised energy providers` role obsolete. This might be the most radical, however, the new system will demand a shift in role for almost all stakeholders in the energy system, including TSOs and DSOs. This includes the development of new regulations and incentives to support the transition. The shift involves a much more extensive collaboration between government bodies, energy providers, and consumers to create a cohesive and efficient framework that can accommodate the unique demands of renewable energy sources.

The most important Energy Sector Policies

The most important policy in 2024 has been the **National Energy System Plan**, otherwise known as the NPE. The NPE is a comprehensive strategy developed by the Dutch government to transition the Netherlands to a climate-neutral energy system by 2050. This plan outlines how the country will generate, transport, store, and use energy in a way that does not negatively impact the climate. The plan provides a vision for the energy system in 2050 and is updated every five years to incorporate new innovations and societal developments. It emphasises a more directive role for the national government in areas such as energy supply, infrastructure, spatial planning, distribution, and conservation. It addresses the need for a maximum supply of sustainable energy, the role of blue hydrogen in the transition phase, and the importance of social aspects like fairness, affordability, and participation. Important outputs are:

- Role for local decentralised energy sources, such as solar panels on the roofs of houses and wind turbines in communities and use of available space in cities and towns for energy generation: think of solar panels on roofs, but also green energy parks nearby;
- Energy infrastructure: developing smart grids that can efficiently distribute locally generated energy;
- Role of local communities in management and distribution of energy: this can be done, for example, through local energy cooperatives or neighbourhood initiatives;
- Energy saving at local level through awareness-raising, energy efficiency and reducing of waste

The new Energy Law will be the legal foundation of the energy transition. This Act replaces the current Gas Act and Electricity Act 1998. It aims to provide a future-proof legislative framework for the changing electricity and gas market and energy system. For example, the bill regulates consumer protection, offers grid operators more options to tackle the full electricity grid (congestion management and cable

pooling), offers households and businesses more opportunities for active participation in the energy market and ensures secure and controlled data exchange between grid operators, market parties and energy consumers. The new law clarifies, simplifies and removes unnecessary differences between regulations for gas and electricity. This is crucial for ensuring maintaining the progress of the energy transition.

Other important policy papers are:

- Climate law and the annual Climate and Energy Outlook (KEV)
    - The Dutch climate targets are laid down in the national Climate Act. In addition to the climate objectives, the Climate Act also describes the policy framework for the climate objectives. Three policy instruments have been included: the five-yearly Climate Plan, the biennial Progress Report and the annual Climate Memorandum.
- The Climate package Jetten 2023. Additional measures, announced by Climate and Energy Minister Rob Jetten on behalf of the cabinet, to ensure an additional emission reduction of approximately 22 megatons to achieve the climate goals in 2030.
- The Collective Heat Supply Act. The new Collective Heat Supply Act (WCW) is intended to accelerate the heat transition. The public interests that the law must safeguard are sustainability, affordability and security of supply. A prerequisite for safeguarding these interests is increased public control. Whether rightly or wrongly, this condition has led to a halt in private investment in heat grids and delays in many projects.
- Policies on the Built Environment. Continuous policies are published aiming to make the built environment more sustainable.

The Multiyear Infrastructure Energy and Climate Program (MIEK), adopted in 2022, initiated and accelerated various projects, including national hydrogen infrastructure, CO2 transport and storage, strengthening the high-voltage grid, and the Delta Corridor from Rotterdam to Chemelot. The 2022 budget includes funding for key infrastructure projects, such as the hydrogen backbone and WarmtelinQ.

2.2 Functioning Innovation Ecosystems

2.2.1 Science, Research and Innovation Systems

Overall innovation metrics

The Netherlands is an Innovation Leader with performance at 128.7% of the EU average in 2023 (Source). Moreover, the Netherlands is ranking the top position among the best-performing Member States in Digitalisation. The country also demonstrates the highest performance increase between 2016 and 2023 in the use of information technologies (43.1% points). (Source) In the global context, the Netherlands is featured as the 7th among 132 economies featured in the Global Innovation Index 2023, and the 5th among 39 economies in Europe. (Source) The key strengths highlighted are public-private co-publications, international scientific co-publications, people with above basic overall digital skills, intellectual property payments and finance for startups and scaleups. Among key weaknesses, the reports highlight non-R&D Innovation expenditures, sales of innovative products, medium and high-tech

goods exports, environment-related technologies. Since 2022, there has been a strong increase in the number of innovative SMEs collaborating with others and enterprises providing ICT training. However, job-to-job mobility of HRST and the number of doctorate graduates significantly decreased. (Source)

Science, Research & Innovation, and digitization policies

- Digital Agenda 2025 (Agenda Digitale Overheid): This document sets out the broader digital objectives for the country, including initiatives to enhance digital skills, cybersecurity, and the implementation of digital technologies across various sectors, including energy.
- The Dutch Digitalisation Strategy 2021: Outlines the government's approach to harnessing digital transformation to improve economic opportunities, societal benefits, and governmental functions. It includes specific actions for energy sector digitalization, such as smart grids and digital energy management systems.
- Netherlands National Research Agenda (NWA): Encourages collaborations across various fields to focus on innovative, interdisciplinary solutions with significant societal impact, including those aimed at sustainable energy and climate goals.
- Smart Grid Development Strategy: It focuses specifically on the development and deployment of smart grid technologies within the energy sector. This includes the use of digital tools for better grid management, energy storage, and the integration of renewable energy sources.

2.2.2 Business environment and Investment Climate

Economic Predictability	In 2023, the Dutch economy slowed down considerably, the inflation totaled 4.1%, which had a negative impact on private consumption, which was also accompanied by low exports. (Source) However, the GDP growth is expected to increase from 0.1 to 0.8% in 2024, compared to 2023. The outlook for 2025 is also positive, with 1.5% GDP growth and inflation decreased to 2%. However, business investment is expected to fall by 1.7% in 2024, after which it should increase again by 1.4% in 2025. (Source) In 2020-2023 the Dutch economy experienced a turbulent period caused by coronavirus crisis, energy crisis due to the war in Ukraine and high inflation. According to the Central Economic Plan 2024, the Dutch economy is returning to a moderate growth trajectory. (Source)
Economic Predictability	In 2023, the Dutch economy slowed down considerably, the inflation totaled 4.1%, which had a negative impact on private consumption, which was also accompanied by low exports. (Source) However, the GDP growth is expected to increase from 0.1 to 0.8% in 2024, compared to 2023. The outlook for 2025 is also positive, with 1.5% GDP growth and inflation decreased to 2%. However, business investment is expected to fall by 1.7% in 2024, after which it should increase again by 1.4% in 2025. (Source) In 2020-2023 the Dutch economy experienced a turbulent period caused by coronavirus crisis, energy crisis due to the war in Ukraine and high inflation. According to the Central Economic Plan 2024, the Dutch economy is returning to a moderate growth trajectory. (Source)
Financial market	The Netherlands offers a thriving business environment for digital energy technologies, with increasing investment driven by sustainability goals. The

following paragraph details which players invest in the energy sector in the Netherlands currently.

Government subsidies:

- **Ministry of Economic Affairs and Climate Policy (EZK)**
  - **SDE++ (Stimulation of Sustainable Energy Production and Climate Transition)**: Provides subsidies for producing renewable energy and CO2-reducing technologies (Source).
  - **SCE (Subsidy scheme for Cooperative Energy Generation (SCE)):** provides subsidies fot energy cooperatives and homeowners' association (VvE) that plan to generate renewable electricity from solar energy, wind energy or hydropower (Source).
  - **Innovation Credit (Innovatiekrediet)**: Financial support for the development of promising and challenging innovations with excellent commercial prospects (Source).
- **Netherlands Enterprise Agency (RVO)**
  - **DEI+ (Demonstration Energy and climate Innovation)**: Supports the demonstration of new technologies that will lead to energy savings and reductions in CO2 emissions for entrepreneurs (Source).
  - **DEI+ (Innovations for natural gas-free homes, neighbourhoods, and buildings):** Supports projects that focus on making homes, buildings, and/or neighbourhoods natural gas-free or natural gas-ready (Source).
  - **TSE Industry studies**: Aimed at projects that test or demonstrate an innovation or fully developed technology in the industry that can reduce CO2 emissions (Source).
  - **Accelerated Climate Investments Industry (VEKI):** Supports projects that will reduce your energy use within (the production process of) a company (Source).
  - **Mission-driven Research, Development and Innovation (MOOI):** a program that supports consortia seeking to develop innovative solutions that contribute to the climate goals for electricity, buildings, industry or biobased circular (Source)
  - **Energy & Climate Research and Development (EKOO) Electricity scheme:** Supports R&D of improvements for the generation of renewable energy, reuse of raw materials and materials and using them as effectively as possible (Source).
  - **SBIR innovation on assignment:** competitions organised by RVO using an open innovation model on behalf of various

	government services. During this challenge, entrepreneurs deliver innovative, solution-oriented products and services for social issues. The government is a potential buyer, also known as a 'launching customer', of the developed products.
	• **Directorate-General for Energy and climate**
	  ○ **Energy Innovation Policy Framework**: Coordinates and funds programs aimed at accelerating the development and use of sustainable energy technologies
	• **Ministry of Infrastructure and Water Management (I&W)**
	  ○ **Green Deals**: Collaborative projects between the government, industry, and other partners to support sustainable initiatives, including those in energy sectors (Source).
	• **Netherlands Organisation for Scientific Research (NWO)**
	  ○ **Perspective Program**: Provides grants for multidisciplinary research projects that focus on societal challenges, including sustainable energy solutions (Source).
	• Every province has a regional development fund coupled to a province. The Netherlands has 12 provinces: Groningen, Friesland, Drenthe, Overijssel, Gelderland, Utrecht, North Holland, South Holland, Zeeland, North Brabant, Limburg, and Flevoland. For example:
	  ○ Limburg Energy Fund
	  ○ ROM Utrecht: risk bearing public entity investor
	  ○ Innovation Quarter (Zuid-Holland): very active in energy, specifically with their Energiiq fund (source)
	  ○ EFRO-programma 2021-2027 (OPZuid): supporting SMEs in the by developing business cases, demonstration in the real environment, pilot production, and initial roll-out or initial scale-up of innovations that can contribute to renewable energy production and smart energy systems, grids and/or storage;
	  ○ **Rotterdam smart energy systems program**
	• **InvestNL**, a large impact investor, very active in energy on a national scale (source)
	• **National Growth Fund (Groeifonds):** A fund that was established to invest in large structural programs that contribute as much as possible to sustainable and structural economic growth in two areas: Knowledge development and Research, Development & Innovation. The Fund has invested a total of € 11 billion in 51 projects in three rounds. In 2024, the round 4 and 5 were cancelled. (Source)
	
	EU subsidies: There are various EU subsidies that focus on sustainability, deep-tech and digitization efforts, like Horizon 2020, Horizon Europe, Digital Europe Programme, EIC accelerator, support from EITs, Innovation Fund, EUREKA, Eurostars, Just Transition

	Mechanism. The Netherlands is actively participating in EU-funded initiatives: it is the 5th country in the EU by participating and the 4th country by the budget share. (Source) **Venture Capital** 1. SET Ventures: invests in European technology companies that impact the future of the energy system. They focus on innovative energy generation, storage, and energy efficiency solutions. 2. Rockstart VC: is an accelerator and venture capital firm that has a specific focus on smart energy. They support startups that contribute to the energy transition, including sustainable energy solutions and smart grid technologies. 3. Shift Invest: focuses on innovations in food and agriculture, clean tech, and bio-based circular technologies, including energy solutions that offer environmental and health benefits. 4. Climate Fund Managers: finances sustainable infrastructure projects in emerging markets, including renewable energy projects. They focus on solar, wind, and hydro projects among other sustainable energy initiatives. 5. Start Green Capital: specialises in investments in sustainable innovation and social enterprises. The firm focuses on early-stage startups and growth companies in sectors such as clean technology, renewable energy, and sustainable development. 6. Rubio Impact Ventures: Invests in impactful startups that address global challenges, including renewable energy and sustainability. 7. Ponooc: Focuses on investments in sustainable mobility and energy, supporting companies that drive the transition towards a cleaner, more efficient energy system. Besides, multiple angel investor groups are active, below is a list: 1. Leapfunder - Offers a dynamic platform for startups and investors, hosting events like Round Table Sessions to facilitate interactions. 2. Investormatch - A network that connects startups with over 1000 angel investors. 3. Dutch Startup Association - Offers support and resources for startups, including connections to investors. 4. FundsUp - Provides a robust platform connecting startups with investors, facilitating discovery, networking, and investments. FundsUp hosts exclusive

	investor events and provides a structured environment for engagement between startups and potential investors. 5. MatchInvest - Focuses on connecting startups with a broad network of investors. This platform allows startups to present their business ideas directly to potential backers, helping them find the right match based on industry and investment size preferences. **Corporate R&D:** Large institutions are also seen actively allocating budgets for digital transformation initiatives in the energy sector. Regardless, many large companies are also investing heavily in innovative solutions. Examples are Alliander, Enexis, Stedin, Tennet. Siemens, Essent, Eneco (have their own venture fund), KPN, IthoDaalderop and many others. **Financial markets overall**: Investing in the energy sector, particularly in hardware-intensive projects, requires significant capital, presenting substantial barriers to entry for new players. Early-stage funding is especially challenging to secure, and while later-stage capital is more accessible, it doesn't guarantee success. The sector's high capital intensity and low margins make cash expensive, reinforcing the dominance of established players who don't face the same financial hurdles. Conversely, businesses focused on software and services benefit from higher margins and better scalability, making them more attractive investment opportunities in the competitive energy market. New market players are stepping into leasing of hardware like batteries and solar panels, hopefully making the barriers lower for new activities.
Legal and Political Settings	The Netherlands had general elections at the end of 2023. It was expected to be held in 2025, however, Mark Rutte`s 4th cabinet collapsed in the summer of 2023, sparing a snap election. The election led to a majority of a party called the PVV, known for its strong rightwing ideology. Right wing policies generally don't support climate change initiatives as fiercely, as they are often restrictive to society and businesses. Nevertheless, the new cabinet recently made energy independence a major goal of the government, sparking a new, strong incentive for digitalisation, deep tech embedment and deployment of renewables. The policy objectives are 1) transitioning away from gas; 2) increasing renewables; 3) grid capacity development; 4) energy independence. The Netherlands has been slow to incorporate essential elements of EU energy regulations into national law, particularly those related to energy sharing. Despite EU directives since 2019 mandating the inclusion of sharing provisions in member states' legislation, the Dutch legislature has not yet fully adopted these changes, which impedes the development of local energy communities. The new Energy law that would facilitate the progressive regulations needed to accelerate the energy transition, especially for local energy systems finally got

	approved in June 2024. Its delay was critical as it was holding back potential advancements in smart grid technologies and renewable energy distribution within local communities. The new energy law provides new rules for data sharing making it easier for households and companies to see their own data or share this with specific suppliers. The collaboration BAS (Source) is working on realising this data sharing. However, insiders told that a narrow approach is being taken, only allowing for limited sharing options. The system is likely not flexible enough to facilitate all the data sharing needed to build energy communities. With digitalisation bringing in new challenges for end-users and incentives not yet in place for socially needed market behaviour, policy should prioritise new principles for for example interoperability and cybersecurity.
Labour market, Human resources and skills	There is a significant demand for skilled professionals in the digital energy sector, driven by startups and technological advancements. The key challenge here is to scale up effective and successful initiatives such as Make IT Work, Cloud IT Academy and Brightlands Services Campus, which train and retrain people in ICT. A broad coalition of public and private parties is developing a scaling-up plan within the framework of the Human Capital Agenda for ICT. In addition, the NL Leert Door (Continuing education in the Netherlands) scheme provides opportunities for free development advice and retraining or further training. Employers in sectors faced with structural labour shortages, such as the ICT sector, can take advantage of a retraining scheme (with €37.5 million in funds and 10,000 places) aimed at hiring and retaining people from other sectors. Another initiative that was introduced in late 2019 is the Knowledge and Innovation Covenant (2020–2023), with the aim to merge various research agendas and various public and private funding sources. In order to strengthen the national knowledge base, technological developments and their impact on society, the government intends to give the digitalisation of the energy sector a central place in the updated National Science Agenda (Nationale Wetenschapsagenda). To bolster the national skills base and adequately prepare for the challenges of digitalization in energy, the Top Sector Energy has implemented the Human Capital Agenda (HCA). This strategic initiative aims to bridge gaps in the labour market essential for the energy transition. By emphasising the need for a large-scale enhancement of competencies, the HCA focuses on improving the quality, equality, and accessibility of training across the sector. This effort is crucial as the energy transition not only shifts the technological landscape but also drives significant employment growth, demanding new skills and substantial workforce expansion (Source). Another initiative is 'People Make the Transition' programme implemented by construction companies, installers, grid operators, and educational and research institutions (Source). It creates training opportunities for reskilling, cooperation between different parties and accelerating technological innovation.

Infrastructure	The Netherlands' energy infrastructure (grid) is one of the best in the world yet faces challenges in adapting to renewable energy transitions. As the country shifts towards decentralised energy generation, digital infrastructure becomes crucial. Smart grids, IoT devices, and energy data platforms are essential for efficient and resilient systems. On the TSO level (high-voltage transmissions), measuring is quite extensive, however, the DSOs aren`t yet sufficiently measuring the low-voltage grid. Gaps in Knowledge on Technical Barriers of the Grids: Previously, there weren't problems with reaching the boundaries of the grid in the Netherlands, therefore maximum limits of components were not properly registered as it simply wasn't necessary. In the Netherlands, there is little or no practical experience with networks that are overloaded at 100% for extended periods. Next to that, there are knowledge gaps in thermal modelling of cables. Thermal limits determine how hot cables and transformers can get before damage or degradation occurs. There are differences in cable behaviour, for example, between overhead and underground lines. The type of material in the area surrounding the cables that form insulation is a limiting factor. Current models have shown limitations, evidenced by older cables performing well beyond their predicted lifespan. A key area for improvement is the development of enhanced thermal modulation insights and transitioning from 2D to 3D models. Next to that, information technology and advanced modelling techniques could play a significant role in managing these uncertainties. Furthermore, the management of grid behaviour necessitates radical changes, including the development of advanced hardware and sensors. These innovations are essential for accurately monitoring and controlling the network, ensuring its resilience and efficiency in the face of growing demands and fluctuations. Given the grid congestion context, there is a need to transition slowly to dynamic loading of the grid. This requires dynamically plotting profiles and accurately predicting warm-up and cool-down times of the cables, which is essential for managing peak loads effectively.

Table 5: Business environment and Investment Climate in the Netherlands

2.2.3 Culture and Attitudes

With ambitious goals to transition to a carbon-neutral economy, there is a significant emphasis on innovation and entrepreneurship within the energy sector. Startups and entrepreneurs in the Netherlands are actively engaged in developing renewable energy technologies, energy-efficient solutions, and smart grid systems. According to data from the Dutch Chamber of Commerce (KVK), the number of startups in the energy sector has been increasing in the past years with a growing interest as well as investment in this area. (Source) The working culture promotes co-creation, inclusivity and multi stakeholder approach, which not only drives technological innovation but also ensures that a diverse range of perspectives and ideas are considered, leading to more comprehensive and effective solutions to the energy challenges.

Collaboration across the quadruple helix

Notably, the country boasts several field labs such as TU Delft's Green Village, where universities collaborate with industry in a deregulated environment to test new ideas and solutions. However, overall the connection between academia, industry, citizen groups and public authorities is less developed and the research outcomes and business insights are not passed quickly. This results in misalignment of the current legislation with important stakeholder needs. In turn, it hinders the realisation of the full potential of the Netherlands' renewable energy sector: while the overall innovation landscape is strong, the convergence (blending or integration of different solutions into one single solution) remains underdeveloped due to the lack of incentives for such collaborations (regulations or tax incentives). Furthermore, in practice it remains challenging to bring together the quadruple helix for better and much needed insights, pilots and policy-making.

Example: Role of Grid Operators
Previously, grid operators played a predominantly passive role. Obtaining permits to develop new infrastructure were not allowed solely based on forecasted needs and predictions. Instead, they were required to demonstrate tangible demand through concrete waiting lists before initiating construction. In the EU, it takes an average 15 years to identify a need for new transmission lines.
Of these, only one year is dedicated to actual construction, while the remaining 14 years are consumed by extensive decision-making processes involving approvals, permissions and detailed calculations to show the actual need for new grid infrastructure.

Moreover, the existing work culture and skill set within grid operators is currently undergoing change. Where some divisions are still primarily oriented towards maintaining the current system with personnel whose skills focus on maintenance rather than innovative practices or collaborating with innovative start-ups, other divisions are understanding the need for change and focusing on end-users' needs. The culture divide between those focused on maintaining the status quo and those pushing for innovation and transformative change is a challenge, making it harder to facilitate the energy transition.

Entry barriers for innovators

Another challenge is a high entry barrier for new entrepreneurs. One reason is that the sector is heavily regulated, and meeting requirements is hard for new players and SMEs. Adding to that, institutions providing financing (both private and public) often prefer companies with more extensive experiences compared to startups, as they believe they are more likely to succeed, further widening the gap between players in the field, and players who aim to enter.

Energy cooperatives are increasing

Energy cooperatives are becoming increasingly popular in the Netherlands, reflecting a deep-rooted cultural commitment to community involvement and cooperation that extends into the energy sector. The number of cooperatives started to skyrocket in 2011. According to data from Energie Samen, the umbrella organisation for energy cooperatives, there are now 714 energy cooperations and 700 resident

initiatives (source), covering 89% of municipalities and involving 131,000 participants. These numbers are constantly growing. More than two-thirds (68%) of all energy cooperatives are working on solar energy projects. In 2023, 146 new solar projects will have been realised. It is estimated that around €165 mln were invested by citizens into the ongoing wind and solar projects. And all together, the energy communities are estimated to contribute an average of around €0.5-1 mln per year to funds for the environment.

Energy corporations and initiatives mean a lot for social acceptance of the transition and can activate new groups to embrace necessary energy changes. They know the local circumstances, invest in each other and combine creative ideas in local solutions tackling many problems at once. However, regulation hinders them constantly[33]. The (perceived) obligation for governments, after a successful start, to use tenders for further funding often results in commercial entities taking over successful local initiatives, simply because they are more experienced in tender writing. This results in the dismissal of local, many times vulnerable, people, undermines community trust in the energy transition, and causes frustration among those who have invested their time and money to improve their neighbourhoods. Our inability to properly secure and incentivise social initiatives with an important impact on the energy transition should be recognised as a barrier that needs addressing.

2.3 Ecosystem descriptions

2.3.1 Regional Ecosystems

The Netherlands' innovation ecosystem map for energy digitalization cannot be strictly divided based upon solely geographical criterion. Due to the country's small size, most energy players, particularly the larger energy companies, have widespread activity across all regions. In this section, we describe the key actors in regions distinguished based on economic activities.

The 6 clusters

Due to economies of scale, efficiency, location, collaboration opportunities and infrastructure, the Netherlands is usually divided into 6 regional cluster. The industry is highly concentrated in 5 regional clusters and a cluster covering the rest of the Netherlands: Northern Netherlands, North Sea Canal Area, Rotterdam-Moerdijk, Zeeland/West Brabant, Chemelot and Other Industries, also known as Cluster 6. (Source) It is perceived that the first 5 clusters are very effective at lobbying for their interests regarding grid congestion at the ministerial level, even though their interests do not align with those of the other companies.

Cluster 6 has developed a Cluster Energy Strategy (CES), where companies from 9 various industries (Food Industry, Metal Industry, Ceramic industry, ICT sector, Oil and gas exploration companies, Waste and recycling sector, Chemical industry, Glass Industry, Cardboard and paper industry) describe their ambitions in CO2 reduction and concrete steps in achieving this. (Source) They collaborate to work out solutions for electrification: to access to new sustainable energy infrastructure and improvement of

[33] No research has been done to the extent that the new Energy law adopted in June 2024 would alleviate these problems.

operational procedures surrounding it, i.e. collaboration across regions and provinces, as well as simplifying permit procedures.

Randstad

- YES!Delft: One of the leading tech incubators in Europe, YES!Delft offers programs that support startups across various sectors, including energy, offering access to expert advice, funding, and a network of industry partners
- Dutch Innovation Factory (DIF): Based in Zoetermeer, DIF is an innovation hub focused on ICT and energy, promoting startups and scale-ups through collaboration with education and research institutions.
- Smart Beach Grid Scheveningen: tackles grid congestion with a mobile battery, optimising local energy usage and supporting the Dutch grid during peak summer demand. It had a significant grid congestion issue, hence the project (Source)

Rotterdam harbour area

This region has traditionally played a major role in north-western Europe, facilitating imports of fossil fuels, as well as producing energy and chemical products.

- PortXL: World's first port accelerator, which also focuses on energy, specifically innovations in clean energy, efficiency, and logistics solutions for the port and maritime sectors.
- Holland Hydrogen One: the port facilitates conversion parks for electrolysers, where the port is constructing the first 200MW green hydrogen factory
- Future Mobility Park: testing ground for sustainable transport innovations.
- Smart Energy Systems Programme: a grant programme of municipality for organisations and entrepreneurs carrying out feasibility studies, experimental developments, or a pilot in the field of Smart Energy Systems.
- Platform Zero: a physical and digital hub for all climate and energy related innovators developing initiatives in Hydrogen, Green Corridor and M4H Energy.
- UP!Rotterdam: a business accelerator for innovative entrepreneurs providing them with access to capital, talent, new markets and networks.

Amsterdam harbour area

An industrial hub focused on integrating green energy solutions into port activities, enhancing logistics efficiency through smart port technologies.

- Schoonschip Amsterdam: Europe's most sustainable floating neighbourhood in Amsterdam, features 46 households with innovations in solar power, heat pumps, and a smart grid, promoting an ecologically and socially sustainable community since early 2020 (Source)
- Smart City Amsterdam: Integrates IoT and data analytics for urban planning and sustainability, creating a model for energy-efficient and smart urban environments.

- Project Amsterdam ArenA: Implements a smart energy system using renewable energy, storage, and smart grid technology to efficiently manage energy use in the Johan Cruijff ArenA.
- Amsterdam Innovation Arena: This hub is a collaboration of companies, governments, and research institutions working on innovative solutions for smart cities and smart energy systems.
- Startupbootcamp Smart City & Living: This Amsterdam-based accelerator program focuses on smart city innovations, including sustainable energy and IoT technologies that enhance urban living.

Westland

This region has the highest density of heated greenhouses which use fossil fuels as their main energy source. Currently, there are several projects exploring the usage of alternative sources such as solar energy, heat network, residual heat, pellet heating system, wood heating system and biogas. System integration and innovation is part of the area's dna.

- Greenport West-Holland: Focuses on sustainable horticulture and integrating renewable energy sources in agriculture.

Groningen

- **University of Groningen**
  - Energy Academy Europe (EAE): A collaboration between academic institutions, research bodies, and businesses focusing on sustainable energy solutions.
  - **New Energy Coalition:** A consortium connecting businesses, knowledge institutions, and governments to work on energy transition projects
- **EnTranCe:** Located at the Zernike campus in Groningen, it serves as a testing ground for new energy innovations. Startups, students, and researchers can collaborate on projects such as smart grids, renewable energy, and energy storage solutions.
- **Hydrogen Valley:** An initiative to develop a comprehensive hydrogen value chain from production to consumption.

Chemelot

Brightlands Chemelot Campus: Situated in Geleen, Limburg, South Netherlands, this campus hosts over 240 companies and institutions, fostering innovation in sustainable technologies and digital innovations. The campus has attracted significant investments, including €45 million in research and development projects, enhancing its role as a catalyst for regional growth. Additionally, Brightlands' collaboration with Maastricht University has led to groundbreaking research in materials science and sustainable processes, further driving innovation in the region.

2.3.2 Energy Ecosystems

In this section, the actors are described shaping the energy field on the national level.

Knowledge institutes

- **Topsector Energie**: A governmental organisation that drives innovation in the Dutch economy, with a focus on digitalisation. The Digitisation programme looks at the cross-system developments that play a role at the intersection of ICT and energy: What are the major movements that are taking place and what do we need to take into account when applying digital technologies in the energy transition? How do we ensure that the future sustainable digital energy system is reliable, affordable and secure?
- **High Tech Campus Eindhoven:** Often referred to as the smartest km² in Europe, this campus houses more than 160 companies and institutions developing technologies in various domains, including energy solutions.
- **Delft University of Technology (TU Delft)**
    - **The Green Village:** A living lab for real-world testing of new technologies, particularly in sustainable engineering and digital technologies.
- **University of Twente (UT)**
    - **Centre for Energy Innovation:** Focuses on the digitalisation of the energy system, developing smart grids, and managing renewable energy integration. UT has participated in numerous projects related to digitalization and robotics, securing significant funding from European research programs.
    - **Fraunhofer Project Center:** Collaborates with manufacturers to develop innovative and integrated solutions.
- **TNO (Netherlands Organization for Applied Scientific Research):** Conducts extensive research in smart grids and energy-efficient buildings.
- **IPKW Cleantech Campus Arnhem:** Industriepark Kleefse Waard (IPKW) is a 90-hectare work location that houses, facilitates and connects sustainable energy-related companies. Together with government, education and business, it is working on the cleantech campus of the future. (Source)

- **Energy Innovation Park (EIP):** Located in Alkmaar, this park is dedicated to fostering innovation in the energy sector, particularly focusing on sustainable and green energy technologies.

Innovative companies

There are multiple innovative companies working on deep tech and digital technologies, such as Essent, WiththeGrid, GIGA storage, Distro Energy, Currentt, Battolyser, Skoon Energy Storage, ZEnMO Simulations, Firan, KPN, Spectral, Resourcesfully, Enexis, IthoDaalderop, Unify.energy, Rethink Zero, TwinTopics, ANWB Energie, NieuweStroom, LYV and Frank Energie.

Public authorities and governmental initiatives

- **MFF BAS**: A collaboration focusing on market facilitation and flexibility in the energy sector, providing platforms and frameworks for data sharing and operational management.

- **National Programme Regional Energy Strategy (NR RES):** A programme supporting regions in creating and implementing Regional Energy Strategies. It does so by developing and sharing knowledge, process support (in decision-making, participation, etc.), data support (analyses, calculation methods, etc.), and knowledge sharing.
- **The LAN:** the National Action Program Net Congestion was established in the Netherlands as a collaborative effort between national government, network operators, the Authority for Consumers & Markets (ACM), regional governments, and private enterprises. This program aims to create more space on the electrical grid by addressing current constraints and planning for future needs. The collaborative efforts are structured along three primary action lines: *Accelerated Infrastructure Development of the Grid, Optimized Network Utilization and Enhanced Strategic Insights.*
- **Netbeheer Nederland**: The association of energy network operators in the Netherlands, which plays a critical role in managing and modernising the energy grid to support the transition to renewable energy.
- **Programma Verduurzaming bedrijventerreinen (PVB)** This very important programme, part of the TOPSECTOR helps local players – park managers, regional authorities and entrepreneurs – to jointly achieve sustainability in their business park. From starting to work together to sustainability strategy, implementation and knowledge sharing.
- **Sustainable Scale-up foundation (SSF):** A a non-commercial network organisation for purpose-driven community (business) development, supported by the Ministry of Economic Affrairs and Climate Policy. Through its programme Energy Scale-up, it aims to accelerate the energy transition by facilitating inclusion of companies with smart innovations into the public discourse. At the moment, the focus is mainly on improving the ecosystem of smart energy hubs at business parks.

Other organisations

E-Laad: A knowledge and innovation centre that researches and tests the smart and sustainable charging of electric vehicles. ElaadNL is an initiative of the joint Dutch grid operators. In collaboration with global manufacturers, E-Laad tests the state-of-the-art technologies for charging electric cars, trucks and buses in the Test Lab in Arnhem.
Confederation of Netherlands Industry and Employers (VNO-NCW): A business association uniting trade associations, companies, SMEs and entrepreneurs, representing in total 90% of private employment in the Netherlands. It represents the interests of Dutch entrepreneurs on the national and EU levels, making sure their voice is heard in politics, public administration and other civil society organisations.

Programme/Project based Ecosystems

The major program and project-based ecosystems of the Netherlands are represented by collaborations between network operators, universities and companies with digital solutions. One of the major topics is energy hubs and their digitalisation.

*An **Energy Hubs** is a smartly managed, decentralised energy system where sustainable energy generation and energy consumption in a specific area are coordinated as much as possible. At the same time, the hub relieves and/or strengthens the upper energy system by balancing the supply and demand*

of different energy carriers within the area as much as possible by combining local production, consumption and storage and conversion.

In the Netherlands, approximately 140 energy hubs are in development, with different stages in progress, ranging from orientation phase to nearing final contractual agreement. The use of energy hubs in the Netherlands marks a strategic shift towards smarter electricity management, elevating net congestion problem. There's currently a vibrant movement in the Netherlands around energy hubs, as they enable the exploration of new models for energy distribution and management. These hubs facilitate cooperation and overcome barriers such as joint contracting, regulations for Energy Management Systems (EMS) and possibilities for i.e industry parks to continue electrifying processes to comply with the mandatory Climate Goals of net zero carbon emissions.

There are many initiatives to facilitate energy hubs in becoming successful by:

- Sharing knowledge and experiences between energy hubs and their representatives
- Providing knowledge and expertise to starting energy hubs
- Identifying barriers in regulations and bring them into consultations for new policies, regulations, codes of conduct
- Identifying new barriers and organising consortiums, working groups to solve them

Important initiatives for this are

- The "**meetingplace**" organised by the Ministry of Economic Affairs and Climate Policy (EZK) and Rijksdienst voor ondernemend Nederland (RVO) in the morning and the "**frontrunners group**" in the afternoon organised by the Sustainable Scale Up Foundation (SSF) in cooperation with RVO, the Ministry, NPRES, PVB and TenneT. It embodies knowledge exchange within the quadruple helix especially involving end users. The topics include new contract forms between companies and distribution network operators and availability of data for simulation models.
- **Mooi Eigen** The EIGEN project consortium consists of thirteen partners: Alliander, Sunrock Development, Ventolines, Recoy, SemperPower, PARKnCHARGE OpCo, Stichting ElaadNL, Over Morgen, Connectr, University of Twente, TNO, Stichting Saxion and Shared Energy Platform. The EIGEN project started at the beginning of 2022 and will last just under four years, until 2025. The intention is that there will then be a standard step-by-step plan ('blueprint') for a large-scale roll-out of energy hubs for business parks. The beauty of such a step-by-step plan is that it offers a generic approach. Not only does it suit various types of business parks, it is also suitable for other local applications. Think, for example, of smart cities and local energy communities.

Improving Knowledge on Maximum Grid Use

Network Operators and universities are working together in many different collaborations (Dutch Power, CIGRE, CIRED, Grid Edge Control, Power Quality in Control, Syneco, Orkest, Life) focusing on maximising grid usage without compromising system integrity.

ORKEST is co-financed by the Ministry of Economic Affairs and Climate Ministry of the Internal Affairs and Kingdom Relations. It falls under the Mission-driven Research, Development and Innovation (MOOI) scheme of the Dutch government and will be active in the period of 2023 - 2027. Orkest aims for optimal

integration of network flexibility and asset intelligence to increase large-scale integration of RES, while maintaining reliability. The project consists of the following activities: development of reliability and ageing assessment tools - Development of twinning between components and systems to accommodate more RES - Optimization methods of solutions for both capacity constraints and component reliability - Ongoing development of Real-time interface - Development and demonstration of Proof-of-Principle.

As a transmission system operator, TenneT plays a crucial role in the development and maintenance of the high-voltage electricity transmission network, facilitating the integration of renewable energy sources into the grid.

MaxLimit Project: TenneT is investigating the extent to which the load on existing grid links can be increased by quantifying the risks of heavier loads and revising calculation models. Models are used to quantify the risk of exceeding thermal limits. The aim is to determine how much additional capacity can be extracted from the grid.

2.3.3 Programme/Project based Ecosystems

The major program and project-based ecosystems of the Netherlands are represented by collaborations between network operators, universities and companies with digital solutions. One of the major topics is energy hubs and their digitalisation.

*An **Energy Hubs** is a smartly managed, decentralised energy system where sustainable energy generation and energy consumption in a specific area are coordinated as much as possible. At the same time, the hub relieves and/or strengthens the upper energy system by balancing the supply and demand of different energy carriers within the area as much as possible by combining local production, consumption and storage and conversion.*

In the Netherlands, approximately 140 energy hubs are in development, with different stages in progress, ranging from orientation phase to nearing final contractual agreement. The use of energy hubs in the Netherlands marks a strategic shift towards smarter electricity management, elevating net congestion problem. There's currently a vibrant movement in the Netherlands around energy hubs, as they enable the exploration of new models for energy distribution and management. These hubs facilitate cooperation and overcome barriers such as joint contracting, regulations for Energy Management Systems (EMS) and possibilities for i.e industry parks to continue electrifying processes to comply with the mandatory Climate Goals of net zero carbon emissions.

There are many initiatives to facilitate energy hubs in becoming successful by:

- Sharing knowledge and experiences between energy hubs and their representatives
- Providing knowledge and expertise to starting energy hubs
- Identifying barriers in regulations and bring them in to consultations for new policies, regulations, codes of conduct
- Identifying new barriers and organising consortiums, working groups to solve them

Important initiatives for this are

- The "**meetingplace**" organised by the Ministry of Economic Affairs and Climate Policy (EZK) and Rijksdienst voor ondernemend Nederland (RVO) in the morning and the "**frontrunners group**" in the afternoon organised by the Sustainable Scale Up Foundation (SSF) in cooperation with RVO, the Ministry, NPRES, PVB and TenneT. It embodies knowledge exchange within the quadruple helix especially involving end users. The topics include new contract forms between companies and distribution network operators and availability of data for simulation models.
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3. Slovakia

Country profile[34]:

Region: EUR

Income: High

Population (mn): 5.6

GDP, PPP$ (bn): 211.1

GDP per capita, PPP$: 38,620

Global Innovation Index, rank: 45

Total energy consumption per capita, kWh[35]: 33888

3.1 Energy Systems State and Challenges

The Slovakian energy system is characterised by a diverse portfolio of energy sources (nuclear power, oil, natural gas, coal, biofuels and hydro). Slovakia's energy system is dominated by net energy imports (68%), with fossil fuels still playing a significant role at the total energy supply level (all the energy produced in or imported to a country, minus that which is exported or stored). Although nuclear remains the largest source of energy at 25%, oil and natural gas both represent 24% and 23% respectively.

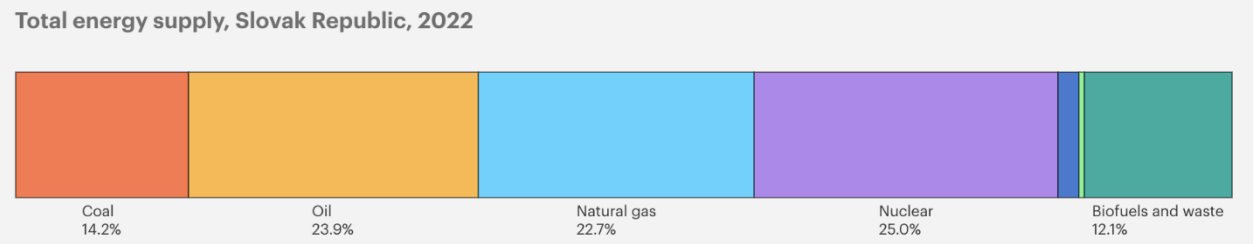

Figure 6: Total energy supply, Slovak Republic, 2022

At a domestic energy production level, nuclear is again Slovakia's primary source of energy production at c. (59%) ahead of biofuels and waste (c.29%) and remaining sources (e.g. hydro, coal, oil, natural gas) all below 5% contribution respectively. Slovakia has one of the lowest shares of wind and solar energy in the EU.

[34] https://www.wipo.int/edocs/pubdocs/en/wipo-pub-2000-2023-en-main-report-global-innovation-index-2023-16th-edition.pdf

[35] https://www.iea.org/countries/slovakia/energy-mix

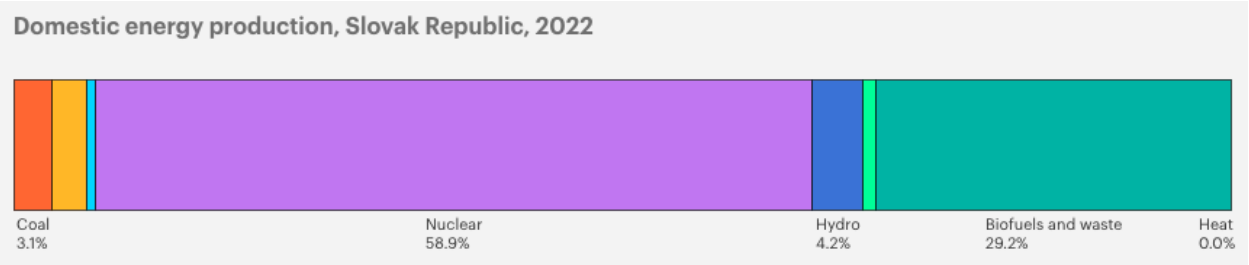

Figure 7: Domestic energy production, Slovak Republic, 2022

For electricity generation, it should be noted that hydro plays a significant role, representing the second largest source of electricity generated (c. 14%) behind nuclear (60%).

Slovakia has a significant dependence on third countries for all main energy sources, with Russia historically the main supplier of both fossil fuel imports and nuclear fuel supplies (in 2022 Russia accounted for nearly 100% of natural gas, oil, and nuclear fuel, and c. 33% of coal imports). Diversification of fossil fuel imports is underway (i.e. substitution of c.33% of Russian natural gas) following the Russian invasion of Ukraine but the dependency remains strong in both nuclear fuel and oil.

A significant element of the slow roll-out of renewables within Slovakia's energy system was a long-term ban on connecting new electricity generators to the national grid which ran for roughly a decade until 2021. Although Slovakia saw an initial growth in deployment of renewable energy sources, particularly PV, in 2010 following the introduction of the Act on Renewable Energy Sources (provisioning support via grid access, mandatory purchase of electricity, feed-in tariff, imbalance settlement by TSO), many of this government backed support was pulled in mid-2011 and for the next decade Slovakia entered a phase which saw minimal non-hydro renewable installations, with the TSO citing a lack of grid preparedness for new installations. In 2021 a new interconnector line to Hungary became operational which ended this phase and has since seen a renewed growth and interest in RES installations. Significant pent up demand within this sector was highlighted in 2021 when the SIEA awarded EUR700,000 in payments in under 30 minutes to small scale non-grid connected PV systems. Despite this recent positive development, this holding period caused significant damage to Slovakia's RES and digital energy progress.

Slovakia is a structurally energy intensive economy (notably in industry (steel), transport and residential sectors), with primary energy intensity around 80% above the EU average, and limited progress in reduction of net greenhouse gas in recent years.

The digitalization of Slovakia's energy sector remains in its early stages, facing several challenges. The adoption of Energy Management Systems (EMS) and Internet of Things (IoT) solutions at both commercial and residential levels has been slow. This slow uptake is reflective of the broader digital maturity issues within Slovakia's small and medium-sized enterprises (SMEs), which often lack the necessary support and resources for advanced digital transformations. The state of the electrical grid also underscores the need for modernization to better integrate digital solutions - whilst efforts are being made to improve the infrastructure and ease of access for renewables, progress is gradual. Additionally, the penetration of e-

mobility infrastructure, such as electric vehicle (EV) charging stations, is low, hindering the adoption of electric vehicles within the country.

Despite these challenges, there are positive steps being taken. It should be noted that in June 2024 SEPS, Slovakia's TSO, received €83 million from the Recovery and Resilience Plan to modernise and digitise the grid via the construction of a new power station and modernization of high voltage lines. This will support the capacity of the transmission system and the grid's ability to cope with the changing source mix in Slovakia's electricity production. Additionally, Slovakia is aligning with European digital energy initiatives to support grid performance, with the recent successful launch of the local operation of the MARI and PICASSO projects which will support grid balancing via the cross-border energy community. Beyond grid capacity, the introduction of Energy Data Centers (EDC) aims to centralise and streamline energy data, which can enhance efficiency and enable better management of energy resources. Moreover, there is a growing recognition of the importance of digital skills and innovation, with initiatives being launched to support the digital transformation of businesses and public service. However, Slovakia still has a long way to go to catch up with more digitally advanced EU countries.

Unfortunately, the Slovak government lacks a comprehensive plan for the transition of its energy sector however multiple different strategies and funds collectively contribute to the sector's transition. There are additional digitalisation strategies which will also be key for the sector's growth which are covered later in this text.

- **National Recovery and Resilience Plan** with an allocation of €6.4BN for relevant reforms and investments - relevant focus areas on development of low-carbon technologies and support for electricity and transport sectors. The Plan includes a **RePowerEU** chapter which allocates 46% of available funds to the green transition. Focus is on accelerated deployment of renewables, expanded capacity of the grid, sustainable transport, increased energy efficiency, accelerated uptake of green skills. 21% of the Plan is dedicated to the digital transition.
- **National Energy and Climate Plan** (NECP) - strategic document prepared by all EU Member States to outline how they contribute to the EU energy and climate goals for 2030, a key document for Slovakia's own energy and climate policy. The Slovak plan has been criticised for and lack of detail, ambition and alignment to EU goals in several areas and is currently under review..
- **Cohesion Policy** and **European Regional Development Fund** (ERDF) will allocate €4.2BN to Slovakia's green transition, with a focus on renewables, reduced energy consumption, public building renovation, and transport networks.
- **Just Transition Fund** will allocate €459M for socio-economic factors related to the energy transition e.g. new jobs, training, technology investment etc.
- **Slovak Energy Policy** – Energetická politika (EP SR) - establishes targets for energy production (incl. renewables), efficiency, security and distribution networks
- **Low-carbon development strategy of the SR until 2030 with a view to 2050 -** the strategy identifies measures to achieve climate neutrality in Slovakia by 2050, primarily aimed at reducing greenhouse gas emissions and promoting sustainable development
- **Enviro-strategy 2030** (Envirostrategy–Greener Slovakia) - vision, framework and results indicators for achieving better environmental quality and sustainable circulation of the economy (e.g. renewables focus, environmental protection etc.)

- **Act No. 251/2012** on Energy and amendments to certain acts - outlines the conditions for business in the energy sector, market access, rights, and obligations of participants in the energy market and provides measures for market function and security of power and gas supply.
- **"Slovakia 2021-2027" Programme** - comprehensive strategic plan to guide deployment of EU funds with relevant focus on innovation, R&I, and green measures in the energy sector

Challenges for Slovakia's energy sector include:

- Transition to a greener more diversified, self-sufficient energy mix with increased focus on renewables
- Energy security and reliability (particularly during winter months, and given global geo-political tensions)
- Energy poverty and affordability (particularly for vulnerable customers, SK government already implementing price caps and other methods to controls soaring energy prices in 2023)
- Energy efficiency (e.g. better energy and environmental performance of buildings - 75% of public buildings require deep renovation)
- More sustainable mobility
- Increased biodiversity protection, adaptation to climate change and development of the circular economy.
- Fragmentation of the funding system and subsidies for green innovations and energy efficient developments among several ministries and institutions
- A lack of professional capacities to implement green developments
- A public and institutional mindset that does not consider climate change or the green transition a priority and has a risk-averse attitude to the sector's innovation and evolution
- Current energy mix, consumption profile, consumer subsidies, and electricity pricing models limit incentives for digitalisation and demand-side led innovation within the energy sector

3.2 Functioning Innovation Ecosystems

3.2.1 Science, Research and Innovation Systems

Science, Research & Innovation status

According to the European Innovation Scoreboard (EIS) 2023, Slovakia is an Emerging Innovator with performance at 65.6% of the EU average (source), Slovakia's innovation performance is increasing slower than that of the EU, thereby increasing the gap. In the global context, Slovakia ranks 45th among the 132 economies featured in the Global Innovation Index (GII) 2023 (source). Between the EIS and GII, key strengths highlighted are high-tech manufacturing, environmental management (ISO 14001 environment/bn PPP$ GDP), creative goods exports, medium and high-tech goods exports, sales of innovative products, non-R&D Innovation expenditures etc. Key weaknesses highlighted include R&D expenditure in the business sector, government support for business R&D, university-industry R&D collaboration, entrepreneurship policies and culture, and venture capital metrics.

Beyond these reports, there is general consensus on the need to improve, strengthen and update the current RDI system. The biggest weakness of the current state of RDI is related to the long-term insufficient

and unsystematic financing of RDI influenced by inconsistent political decisions, brain drain and outflow of experts (source), and challenges such as immature technology transfer practices. In order to improve the startup ecosystem, the government has set three subsequent strategic goals: 1.) creation of a regulatory environment without unnecessary barriers for the emergence and operation of startups in the market, 2.) establishment of infrastructure and services to support aspiring entrepreneurs, and 3.) sufficient public-private financing for startups in the initial stages, when startups must overcome the so-called "Death Valley" and often face extinction before bringing their product to market.In the period following the adoption of the Concept

Energy-sector specific R&I

Regarding energy specific R&I, Slovakia has a number of strategies, plans, and structural funds in place to support this, such as its 'National Recovery and Resilience plan - decarbonisation of industry' (2021) which has allocated €368M to energy efficiency and innovative decarbonisation technologies, the "Slovakia 2021-2027" Programme, which represent €12.6BN of EU investment in Slovakia, with first and second priorities 'a more innovative slovakia (€2BN allocation to support R&I and digitalisation, enhance R&I capacities and competitiveness of SEMs, and strengthen academic-industry cooperation), and a greener slovakia (€4.2BN to support renewable energy, reduced energy consumption, and €2BN in sustainable transport) (source), and the National Hydrogen Strategy. Public institutions such as the Slovak Innovation and Energy Agency have been created to support the realisation of these ambitions ranging from distribution of funds to consultancy for SMEs looking to complete an energy transition.

Science, Research & Innovation, and digitisation policies

- **The 2030 Digital Transformation Strategy** for Slovakia is a key pillar for Slovakia's digital transition and R&I activities. The Strategy (source) puts primary emphasis on current innovative technologies such as AI, IOT, 5G Tech, Big Data and Analytical Data Processing, Blockchain and High-Performance Computing. The strategy incorporates elements and funding from Cohesion Policy instruments and other EU level programmes and facilities, and is aligned with national strategies and action plans and approaches the digitalization challenge on 3 key level: 1) Concepts and policies ensuring innovation in selected sectors and segments; 2) Innovation laboratories as a tool for experimenting with new formats of public administration; 3) New approach to projects.
- **Strategy for Smart Specialization of the Slovak Republic 2021-2027 (RIS3 SK)** is a core document for Slovakia's R&I excellence and R&I-led economic growth with a focus on 1) Digital transformation (Industry 4.0), 2) Transition to an environmental and energy-efficient economy, 3) Development of Slovak regions, including in the area of agriculture.
- **The National Strategy for Research, Development and Innovation until 2030** is an umbrella strategic document that determines the intentions, goals and priorities of the Slovak Republic and the principles of good management and efficiency in the field of research, development and innovation. This was approved at the end of March 2023 and outlines the following targets:
    - Public R&I spending increase by an average rate of 14% per year until 2030, reaching around €1 billion by the end of the decade.
    - Along with private investment in research, the goal is to get the country's R&D intensity – the total R&D expenditure as a percentage of a country's gross domestic product – up to

the EU average of 2%. Currently, R&D intensity hovers around 0.9%, one of the lowest in the EU (source).
    - Move Slovakia from 24th to 14th place in the European innovation ranking.
    - Increase the share of private sector investments in science, research and innovation from 0.5% to 1.2% of GDP.
    - Increase trust and collaboration across the research and innovation ecosystem.
- **Slovak national energy and climate plan (NECP)** - Description in list of energy strategies above. Key document relating to the digitalization of energy sector.
- **National Cybersecurity Strategy 2021-2025** - strategic approach of Slovakia to cybersecurity including increased digital skills and competences in the field of cyber and info security
- **The National Digital Skills Strategy of the Slovak Republic and the Action Plan 2023-2026** (2022) - outlines digital transformation as national priority, focus on institutional background, ICT and digital skills of young people and labour market, and digital inclusion
- **Action plan for the digital transformation of Slovakia for the years 2023-2026** - outlines national goals for digitization, focus on business and economy, deployment of digital tech and resilient society, digital ecosystems and infrastructure

National Digital Decade Strategic Roadmap of the Slovak Republic - strategic roadmap document incorporating elements from numerous digital national strategies and action plans to set strategic goals for 2030 and means for monitoring and measuring progress.

3.2.2 Business environment and Investment Climate

Economic Predictability	The Slovak economy has shown resilience to the energy crisis, but growth has slowed due to high inflation, reduced foreign demand, and tighter financial conditions. The pandemic and energy crisis have worsened public finances, necessitating steady fiscal consolidation to improve long-term sustainability amid an ageing population. More consistent carbon pricing and incentives for green investment would support sustainable growth. Economic activity is expected to accelerate in 2024, driven by private and public consumption and a rebound in exports due to stronger external demand. Government support will continue to mitigate high energy prices, and real wage increases will boost private consumption. However, investment growth will be limited in 2024 after a 10.6% jump in 2023 from EU fund utilisation, but is expected to pick up in 2025 with further EU fund absorption. Real GDP growth is projected at 2.2% in 2024 and 2.9% in 2025. The public deficit increased to 4.9% of GDP in 2023 and is expected to remain high at 5.4% of GDP in 2025 without consolidation measures. Slovakia faces challenges with weakening cost competitiveness, negative external balance, rising house prices, and high household debt.
Financial market	The EC's 2023 Country Report - Slovakia outlines a return to pre-pandemic levels of GDP, however moderate economic prospects for 2023 with a declining level of cost competitiveness globally, high inflation, energy prices and supply chain disruptions (2022), and tight labour supply. Slovakia has pledged considerable EU structural funds towards the twin digital and energy transition, with €2.17 billion of its €6.3 billion Recovery and Resilience Plan towards green investments in energy efficiency and building renovation, renewable energy, sustainable transport, decarbonization, and climate adaption and biodiversity as well as c. 40% of the €13.6 billion of European Structural and Investments Funds available to Slovakia in the 2021-2027 programing period targeted at green investments. Slovakia has well documented challenges with the allocation and distribution of these funds. Additionally, the energy sector specifically is the primary beneficiary of government subsidies (receiving pre-energy crisis €800m EUR per year) from RES feed-in-tariffs through schemes to support clean energy investments (e.g. storage, efficiency, low-carbon transport and fuels). Despite this, Slovakia still has relatively low rates of public and private R&D investment. Amid high energy intensity, the green transition lacks sufficient investment in energy efficiency, renewable energy, and the circular economy with VC investment as a percentage of GDP below the EU average, public expenditure on R&D financed by business enterprise (national) as a percentage of total public R&D expenditure significantly below the EU average (1.98% in 2020, in comparison to the EU average of 7.45%), and R&D intensity significantly below the EU average, driven by the low levels of public and private expenditure on R&D (041% and 0.52%

	of GDP respectively, 2021). As a result of this, commercialisation of research is held back by the lack of innovation spending and the lack of business engagement with higher education institutions.
Legal and Political Settings	As outlined above through the high proportion of structural funds allocated to the energy transition, Slovakia has political and financial capacity to support its digital energy transition however there is significant climate / net zero scepticism across the political and societal sphere and a strong fossil fuel / incumbent lobby that holds back major progress. Key policies supporting the energy transition include: • twin transition includes the national chapter on REPowerEU legislation within the Recovery and resilience Plan (RRP) • The integrated national energy and climate plan (NECP) in Slovakia for the years 2021 - 2030 (focused on 5 key dimensions: decarbonization, energy efficiency, energy security, internal energy markets and research, innovation, and competitiveness) • Low-carbon development strategy of the SR until 2030, • Environmental Policy Strategy until 2030 • The newly proposed Climate Change and Low-Carbon Transformation Act (first or its kind climate law in Slovakia), • Intelligent Industry Action Plan, • Research and Innovation Strategy for Smart Specialization, • Whilst the digital transformation is being supported by: • National digital skills strategy of the Slovak republic and action plan for the years 2023 – 2026 • The national IT Academy - Education for the 21st Century project, • the Learning Slovakia Strategy, • The Single Digital Market Action Plan, • Strategy paper for the area of digital services growth and next generation access network infrastructure (2014-2020) Despite this breadth of legislative and policy support, one of the key challenges facing Slovakia's twin transition is a lack of coherence and quantifiable objectives across its policy landscape An additional challenge for Slovakia is a lack of open data on various elements of energy usage (e.g. electricity consumption) and broad reluctance around data sharing. The Slovak Republic has made sound progress in introducing a market-based regulatory framework for the energy sector and a programme to restructure state-owned energy enterprises. Following legal unbundling, the five biggest energy companies have been privatised, either partially or entirely. For this reason, every

	consumer has the right to freely choose their electricity and natural gas supplier. (source)
Labour market, Human resources and skills	While Slovakia's labour market has seen a recovery from the pandemic, it is facing considerable challenges in both productivity (PPS per employee for 2021, at 74% of EU average), employability, retention and labour force participation, and an export-driven growth model based on low labour costs in industrial production, which is facing challenges regarding automation, component shortages and the transformation towards electromobility. Labour challenges are more pronounced outside Slovakia's capital region, particularly in the east of the country. A key challenge in the digital energy innovation space is the low quality of the scientific base which results in a low ability to retain researchers and attract students. *Slovakia possesses significant digital and energy development potential, as evidenced by its classification as a 'very high development' nation on the Human Development Index (source), however one of its major challenges across the workforce, and particularly in the areas of innovation, is the issue of brain drain. Measures have been designed and are being implemented to reverse this however these are not immediate fixes.* Despite the HDI ranking, according to the Digital Economy and Society Index ("DESI") 2022, a complex review of development levels of the digital economy and society in the EU (focus on connectivity, human capital, use of internet services, integration of the digital technology and digital public services), Slovakia ranked 23rd out of 27 EU Member States, below the EU average on all dimensions. *This is reinforced by EC data which shows that only 13% of businesses in the Slovak Republic are highly digitalised, and 50% has a very low level of digitalisation, compared to 18% and 46% as the EU average (European Commission, 2019b), and* the fact that 34% of all workers active in the Slovak Republic face a high risk of losing their job because of automation with another 31% likely to face significant changes to their job (Nedelkoska and Quintini, 2018). This combined share is higher in the Slovak Republic than among any other jurisdiction for which comparable data are available (see Figure 7.3) (source).
Infrastructure	Slovakia's energy infrastructure is a crucial aspect of its economic stability and resilience. The country relies on a diversified energy mix, including nuclear, hydroelectric, natural gas, and renewable sources. Nuclear energy plays a significant role, with the Bohunice and Mochovce nuclear power plants providing around 55% of the country's electricity. This reliance on nuclear energy helps Slovakia maintain a stable and relatively low-carbon electricity supply. Hydroelectric power is another key component, contributing about 14% of the electricity generation. The country's geographical features, with several rivers and mountainous regions, make it well-suited for hydroelectric projects. Natural gas,

	largely imported from Russia, remains a vital part of the energy mix, used for both electricity generation and heating. Slovakia has made strides in developing renewable energy sources, particularly solar and biomass, but these still constitute a smaller portion of the overall energy mix. The country is working towards increasing its renewable energy capacity to align with EU climate goals and reduce dependence on fossil fuels. The development of Slovakia's energy grid is relatively advanced, featuring extensive interconnections with neighbouring countries. This allows for a reliable energy supply and enhances energy security. However, the grid requires further modernization to handle increasing renewable energy inputs and improve overall efficiency. Investments in smart grid technologies, energy storage solutions, and infrastructure upgrades are necessary to enhance grid resilience and sustainability. Notably, Slovakia has its first Energy Data Centre (EDC) of market data as of October 2023, with the centre's full functionality planned for July 2024. EDC allows even small participants to operate and share data with end customers, simplifies data exchange, reduces administration, and supports smart market solutions by combining centralised and distributed data. Despite its strengths, Slovakia's energy infrastructure faces challenges, such as the need for modernization and increased energy efficiency. The recent energy crisis has highlighted the importance of diversifying energy sources and improving energy security. Investments in smart grids, energy storage, and renewable energy projects are essential for Slovakia to enhance its energy infrastructure and ensure long-term sustainability and resilience.

Table 6: Business environment and Investment Climate in Slovakia

3.2.3 Culture and Attitudes

In Slovakia, a strong entrepreneurship culture is still in development, with a relatively fragmented approach to entrepreneurship training and skills development, and startup support, that lacks coordination. Despite this, numerous initiatives have been designed and are being implemented to create the entrepreneurship culture required for the digital energy transition. These include the SlovakBusiness Agency, the largest provider of publicly-funded business development and entrepreneurship support in Slovakia, the National Business Centre (NBC) in Bratislava, the Slovak Innovation and Energy Agency (SIEA) as a key implementation agency, numerous business associations targeted at promoting entrepreneurship skills development (Entrepreneurs Association of Slovakia (ZPS), the Young Entrepreneurs Association of Slovakia (ZMPS), the Junior Chamber International Slovakia (JCI), etc.) which deliver services such as the Young Innovative Entrepreneur Competition. Various coworking and incubator spaces organise and promote entrepreneurship skills development, mainly through workshops or mentoring activities. An example is the TUKE start-up and incubator centre at the Technical University of Košice, with links to the Regional Hub of the European Institute of Innovation and Technology (EIT). TUKE

also runs an Innovative Idea Competition for innovative ideas, projects and business solutions from young innovators. Similarly, the University Technology Incubator at the Slovak University of Technology in Bratislava runs a series of events that help build entrepreneurship skills, including Hackathons. Companies hosted by the incubator are required to attend at least half of the events.

At both societal and institutional levels there are considerable cultural and awreness problems regarding the importance of the energy transition from a climate perspective (not just energy efficiency as cost saving) which hinders progress and the ability to build momentum. This is repeated wihtin the political ecosystems. Additionally, state support for innovation is regularly characterised as overly bureaucratic and risk averse which acts as a deterrent for innovators from accessing the available support.

Regarding entrepreneurship within the energy sector specifically, despite the mechanisms above, there is limited entrepreneurship support specifically targeted at the energy sector hence Slovakia's mid-table position in ITIF's Global Energy Innovation Index (2021), with Slovakia ranked 20th out of the 34 nations evaluated (source). There have nonetheless been indications of further pushes in entrepreneurship and innovation support in the energy sector with 2 of Slovakia's 6 recently established Digital Innovation Hubs incorporated energy transition as a core focus, offering new opportunities to future founders and SME owners.

3.3 Ecosystem descriptions

3.3.1 Regional Ecosystems

Bratislava region innovation ecosystem

Overview

As the capital and Slovakia's economic and political centre, Bratislava has the most advanced innovation system, boasting a high population share with higher education, substantial employment in mid- and high-tech industries, relatively robust public sector R&D spending, and an above-average volume of joint publications between the public and private sectors. It is considered a "moderate innovator," reaching 84.1% of the EU innovation average but spearheading innovation in Slovakia, reaching 139% of the national average. However, its weaknesses include a limited number of patents and high-quality scientific publications (source). Overall, the city has not yet realised its innovation potential. Moreover, the guiding Regional Innovation Strategy is currently in the process of updating.

Ecosystem actors

- Knowledge Institutes: Five universities out of thirteen in Bratislava include programs in either entrepreneurship or science (source); 1 leading research institute (Slovak Academy of Sciences).
- Business actors: Large businesses, numerous SMEs, and startups.
- Social Organisations: Various alliances and networks.

Knowledge Institutes in Bratislava include five key actors: the Comenius University (CU), Slovak University of Technology (STU), and the Slovak Academy of Sciences (SAS), Kempelen Institute of Intelligent Technologies (KINIT), and Slovak Centre of Scientific and Technical Information (SCSTI).

- The STU is one of Slovakia's most successful organisations in the H2020, raising 4.5 million EUR in 44 participations.
- SAS is a non-university institution fostering the advancement of science in the areas of basic and strategic applied research.
- KINIT is an independent, non-profit institute dedicated to intelligent technology research.

Overall, however, the universities do not adequately fulfil employers' expectations in terms of both the quality and quantity of graduates (source).

Business Actors

Bratislava's entrepreneurial ecosystem received an average rating of 5.61 out of 10 according to the Entrepreneurial Ecosystem Quality Composite Index (ESI), and the innovation levels of its SMEs are low (source). A major business actor in the region is Volkswagen, the country's fifth largest employer (source). Green-tech companies in the area include:

- GA Drilling, a drilling and geothermal energy company with technology for carbon-free independent local sources of energy.
- InoHub Energy provides tailor-made commercial solutions for stationary battery storage with a renewable source.
- SPEAR Hydro is a floating hydro power plant that provides clean and stable electricity by harnessing the natural flow of rivers.
- InoBat specialises in innovative electric batteries.
- PowereX is an aggregator and virtual power plant operator.
- Fuergy specialises in battery optimisation with their own battery storage system.
- AgeVolt is a charging platform for electric cars, which is co-financed by the European Union.
- GreenWay develops charging systems for EVs.

Another significant corporate actor in this area includes Civitta Slovakia a.s. which provides consulting services in Slovakia, focusing on business advisory, innovation, and research.

Relations and interconnections

Businesses have minimal involvement in the city's operations and lack an established relationship with it (source). Bratislava's Urban Innovation Strategy states that the startup community indicated the need to integrate the infrastructure across the V4 region and leverage the capital city's potential and strategic geographic location as a central hub with strong connections to neighbouring countries. Nevertheless, there are various partnerships between public, private, and academic entities in the Bratislava region:

- European Digital Innovation Hub Bratislava is a consortium of six entities from the public, private, and academic spheres
- The Slovak Battery Alliance fosters the development of a competitive and sustainable battery industry in Slovakia by promoting collaboration among stakeholders, supporting innovation, and advocating for favourable policies.
- The Slovak Organization for Research and Development Activities (SOVVA) supports and promotes research, development, and innovation in Slovakia by facilitating collaboration between academia, industry, and government.
- CEVIS Association is a cooperation of the Slovak University of Technology, Comenius University and the Slovak Academy of Sciences.

- The Bratislava Innovation Team drives innovation and sustainable development in Bratislava by implementing smart city projects, fostering technological advancements, and enhancing the city's quality of life.
- University Technology Incubator (STU)
- CU Incubator

Innovations produced & notable projects

The limited but spurring innovation system in Bratislava has produced technologies in medicine, waste management, and geoservices. Some other notable projects include:

- Climathon Bratislava
- Digitization of the city's sports grounds

Case Study

Bratislava City Lab serves as a platform for conducting controlled experiments and pilot programs to test innovative solutions. These projects are aligned with key research and innovation themes, including optimising urban mobility, adapting to climate change, enhancing energy efficiency and neutrality, and making data-driven decisions.One of the pilot projects focuses on collecting anonymous mobility data and deploying various types of parking sensors to evaluate their performance in a real urban setting.

Einpark Building by CORWIN: the first carbon-neutral building in Slovakia, fulfilling the highest certification criteria of LEED Platinum (Leadership In Energy & Environmental Design). The building's modern structure exemplifies contemporary architectural design and sustainable building practices including the integration of numerous digital solutions to optimise energy efficiency. Einpark has a sophisticated digital building management system that goes beyond traditional temperature setting but also focuses on the quality of air by monitoring CO2 levels. From the social side, Corwin focused on active communication and advocacy approaches, which include education of tenants on sustainable practices. The project is a result of Corwin Real Estate's commitment to enhancing urban living through thoughtful and responsible development.

Western Slovakia innovation ecosystem

Overview

Western Slovakia ranks among the "emerging innovators," reaching 85.4% of the national average and only 51.6% of the EU average in 2023, rendering it Slovakia's least developed NUTS2 region. The three regions of the area are currently developing their innovation strategies. However, there are commendable efforts at sustainable urban development, especially in Trnava.

Ecosystem actors

Only the Trnava region within this area has its coordinating body, the Regional Innovation and Development Agency (KIRA), whose activities span from supporting entrepreneurship, aiding socially and otherwise marginalised individuals, and bolstering tourism. Further, this non-profit organisation hosts yearly hackathons, "Kiraton." Otherwise, research and industry remain very loosely connected.

Knowledge Institutes

These are the most notable universities in terms of innovation in the energy sector:

- The University of Ss. Cyril and Methodius that possesses a Scientific and creative park as well as several Centres of Excellence in the realm of energy and innovation sectors.
- Slovak University of Agriculture in Nitra focuses, among other things, on biotechnology within the energy sector.
    - Slovakia's seventh most successful organisation in the amount of contributions received from H2020

Business Actors

A notable industry player in the region is PSA Peugeot Citroën. The nascent startup environment in Western Slovakia includes these companies:

- Daitable provides smart energy management for industries
- GreenBat GreenBat focuses on the operation of battery storage, photovoltaic power plants, and the aggregation of resource flexibility for the regulation of energy networks.

Relations and interconnections

- Industry Innovation Cluster consists of nine entities from various manufacturing industries aiming to accelerate innovation.
- INOVATO is a network of entrepreneurs and experts from various industrie serving as a laboratory for innovative ideas.
- The Trnava University collaborates with the municipality, and the STU faculty in Trnava.

Innovations produced & notable projects

- The project "Future differently" ("Budúcnosť inak") provides pupils with a platform to engage with and study digital technologies.
- Trnava is the first city in Slovakia to install photovoltaic panels in all elementary schools and was also one of the first cities in the country to lead on the installation of EMS within its portfolio of public assets to support intelligent management

Case Study

Trnava has been building a smart urban infrastructure. For instance, it monitors the daily production of photovoltaic panels. Further, it has an intelligent traffic management system at traffic lights connecting individual junctions, increasing their traffic performance and road safety. IoT elements (magnetic detectors) record passing vehicles and adapt signal plans to the current situation. Traffic information boards at city entrances provide drivers with information on the time needed to reach selected points of interest, potential hazards on the route, accidents or detour routes during traffic jams.

Central Slovakia innovation ecosystem

Overview

Central Slovakia ranks among the "emerging innovators," reaching 94% of the national average and only 56.9% of the EU average in 2023. The area has seen its innovation capacities increase in recent years, particularly in the city of Zilina implementing numerous projects. However, the area as a whole lacks the necessary infrastructure, human capital and industry-academia interconnections.

Ecosystem actors in the area are relatively loosely connected. The innovation centre Inovia in Zilina is an interest association of legal entities aiming to create conditions for partnerships between companies and academic institutions. Its activities include (1) the Inovia accelerator, (2) Inovia Startup Forum – a regular open event to foster a community interested in startups, (3) a high school business program, and (4) Innovation of the Zilina region – an annual startup competition. The Science Park of the Zilina university also offers an incubator. The less active part of the area, the Banska Bystrica region, has its own innovation agency called "Dobry kraj" that coordinates innovation activities. The innovation centre Innolab allows individuals or startups to test their ideas or create prototypes by providing technological setup.

Knowledge Institutes

- Zilina university (UNIZA) is involved in various research projects and initiatives that relate to digital technologies and energy
- Technical University in Zvolen (TUZVO) with ecological, woodworking, forestry, and technical faculties
- Numerous SAS institutes, including an innovation centre Inoval for aluminium processing

Business Actors

A notable industry player in the region is Kia Motors Slovakia. The nascent startup environment in the area includes these companies:

- Emon.app offers a spectrum of useful tools for the management and control of energy consumption.
- IPESOFT develops and provides software solutions for industrial automation, energy management, and smart systems.
- Greenlogy is a green energy and virtual green battery supplier.
- Sun Powered Systems creates sustainable photovoltaic solutions.
- eSYST developed software for energy optimization.
- Enertec supplies photovoltaic solutions.
- Stefe supplies heat created from biomass.

Relations and interconnections

Local interconnections:

- The collaboration of UNIZA and SAS in order to improve the provision of higher education and contribute to the development of science, education and culture of society in the form of a "scientific cluster".
- The collaboration of UNIZA, the Center for Technology Transfer (CTT), and the Slovak Centre of Scientific and Technical Information in technology transfer projects.

Connections to international actors

- UNIZA is a part of Pioneer, an EU-funded alliance of 10 European universities oriented toward traffic advancements and smart urban planning.
- UNIZA collaborates with InCities in organising a Sustainable Mobility Innovations course.
- TUZVO collaborates with the company GEVORKYAN, fostering research-industry interconnections.
- TUZVO collaborates with the National Forestry University of Ukraine.

Innovations produced & notable projects

- ERAdiate – Enhancing Research and innovation dimension of the University of Zilina in intelligent transport systems – received 2.1 million EUR from the EU.

Case Study

Numerous innovative transformations within the city are only in the early stages. For instance, Zilina serves as a pilot for ROBIN's circular bioeconomy solutions at regional levels. The regional agency of Zilina, the Pedal consulting group, and ROBIN will collaborate with the Slovak Bioeconomy Cluster to promote cooperation, networking, innovation and mutual exchange of information between cluster members and other stakeholders in agri-food and bio-based sectors.

Eastern Slovakia innovation ecosystem

Overview

Eastern SLovakia ranks among the "emerging innovators," reaching 94.7% of the national average and only 57.2% of the EU average in 2023. The most important sectors of industrial production in the region are metal production and metallurgy, automotive industry, mechanical engineering, woodworking, information technology and electrical engineering (source). The region still has poor links between research institutions and enterprises, as well as a low level of commercial exploitation of R&D infrastructure, making technology transfer one of the utmost priorities of the region (source). Moreover, the inequality between the urban and rural areas is tremendous, with the city of Kosice pioneering innovation in the region.

Ecosystem actors include several universities and business actors as listed below. There are two overarching innovation coordinating bodies in the area – the Innovation Centre of the Kosice region (ICKK) and the Innovation Partner Centre (IPC) in the Presov region. ICKK oversees the implementation of the Regional Innovation Strategy, fosters talent through high school programs and various competitions, provides 6 startup accelerators, and offers support for SMEs.

Knowledge Institutes in the area encompass three universities, several institutes of the Slovak Academy of Sciences (SAS) based in Kosice and Presov, and numerous research institutions, such as Centres of excellence, competence centres, science parks and research centres. The weaknesses in academia include a relatively low number and quality of graduates, under qualification of educators on various levels, and brain drain to the Western part of the country or abroad.

These are the key knowledge institutes:

- Technical University of Kosice (TUKE) launched the University Science Park Technicom, a support platform providing the required infrastructure for collaborative applied R&D with a link to practical support for the corresponding innovation activities, business acceleration and knowledge and technology transfer through the established structures - the Start-up Centre and the TUKE Incubator.
- The Pavol Jozef Safarik University (UPJS) received 70 million EUR from the EU Structural Funds between 2007-2020 for a total of 34 projects. The university focuses on, among other things, the advancements in the energy sector, for example, in energy storage.

Business Actors

The largest employer in the area is U.S.Steel, a steel manufacturer. The innovative startup scene is in its nascent stage. Annually, there are 40 startups created in the most developed part of the area (Kosice), with only a few focusing on climate-related issues. Some of the innovative startups include:

- Ceelabs develops solutions for information gathering and SmartGrid network management.

Relations and interconnections

Local interconnections:

- Cassovia New Industry Cluster (CNIC): As one of the pillars of ICKK, CNIC is a centre of excellence in science and technology transfer, an association of private and public legal entities aiming to create a new, knowledge-based industry in the region.
- Region 30 (Kraj 30): 30 organisations aiming to transform the Kosice region by 2030.

- Cluster IT Valley is an association of 53 actors aiming to create a regional partnership between IT companies, universities, and local municipalities. Amongst their activities is the IT Creativity Lab equipping students with critical thinking skills and connecting them with mentors from the IT and business spheres.
- AT+R cluster unites local governments of the Kosice and Presov region, universities in Kosice and Zilina, private research companies, and the Slovak Academy of Sciences. It supports innovation in mechatronics, robotics, intelligent manufacturing, and advanced materials through projects, technology transfer, and business development training.

Connections to international actors:

- UPJS's collaboration with EIT Digital, Europe's largest digital innovation ecosystem, through the InnoChange project which aims to enhance the entrepreneurial and innovation capacity.
- Collaboration with the World Bank in the Catching-up Regions project.

Innovations produced & notable projects;

- Medipark is a university biomedical science and technology park under construction aiming to become a leading centre for applied research and transfer.
- Promatech, the Research Centre of Advanced Materials and Technologies, fosters collaboration between academia and industry in applied material research, enhancing the competitiveness of Slovak industry by integrating new materials and technologies into production.
- Hydrogen strategy for the Kosice Region was the first hydrogen strategy in Slovakia.

Case Study

"Innovate and do business" is a high school educational program aimed to foster innovation and entrepreneurship amongst youth conducted annually, culminating in the "Founders challenge," a competition of startups that the high school students create. The project provides support throughout as well as after the competition for the most successful companies. 12 early bird startups were created in 2023.

3.3.2 Energy Ecosystems

Overview

Sector innovation ecosystems in the energy sector in Slovakia are formed around a handful of key national players that represent the industry (Slovenské elektrárne, SPP, ZSE, SSE, VSE), smaller private enterprises, and academic institutions (SAS, STU, TUKE, KINIT, SCSTI). Further, there is a wide network of NGOs working on frameworks and pilots for decentralised and sustainable energy solutions, energy cooperatives, communities, financial instruments etc. (MTVSZ, Energia Klub, Transformátor).

Ecosystem actors

- **Knowledge Institutions:** Slovak Academy of Sciences (SAS), Slovak University of Technology (STU), Technical University of Košice (TUKE), Comenius University (CU), Slovak Centre of Scientific and Technical Information (SCSTI), Zilina University (UNIZA), Kempelen Institute of Intelligent Technologies (KINIT)

- **Incubators and Accelerators:** InnoEnergy Hub Slovakia, Slovak University of Technology (STU) Incubator, Technical University of Kosice (TUKE) Incubator
- **Corporations:**
    - Major producers: Slovenské Elektrárne, Slovenský plynárenský priemysel (SPP), Eustream a.s.,
    - Renewable energy startups: SPEAR Hydro, InoHub Energy, InoBat, PowereX, Fuergy, AgeVolt, Greenlogy, GreenWay, GreenBat
    - Distributors: Západoslovenská energetika (ZSE), Stredoslovenská energetika (SSE), Východoslovenská energetika (VSE), Slovak Electricity Transmission System (SEPS)
    - Others:
        - Okte a.s. operates short-term electricity markets, manages imbalance settlements, provides central invoicing, and handles data management in Slovakia's electricity sector. The company also issues guarantees of origin for renewable energy.
        - Energy Data Centre (EDC) introduced in 2023 aims to centralise and streamline energy data, which can enhance efficiency and enable better management of energy resources.
- **Investors:** Slovak Investment Holding, Slovenská sporiteľňa (SLSP), Všeobecná úverová banka a.s. (VUB), IPM Growth, Plán Obnovy, G-Force s.r.o., Innovations and Technologies Fund, Neulogy Ventures, Janom Investments
- **Regulatory bodies:** Ministry of Environment of the Slovak Republic, Ministry of Investments, Regional Development and Informatization of the Slovak Republic, Slovak Innovation and Energy Agency (SIEA), Research and Innovation Authority (VAIA)
- **Civil society:** Slovak Renewable Energy Agency, Slovak Climate Coalition, Slovak National Hydrogen Association, Women in Energy, Slovak Organization for Research and Development Activities (SOVVA)
- **Other stakeholders:** IT Valley Kosice, Slovak Smart City Cluster

Relations and interconnections

These actors collaborate oftentimes through various clusters interlinking more entities with similar objectives, either on a regional or national level. Further, they cooperate in programs and projects aimed at advancing energy technologies, research capabilities, and the entrepreneurial environment in the country. Key collaborations focus on research and development, pilot projects, and knowledge sharing to foster innovation in sustainable energy.

Innovations produced & notable projects

Innovations include energy storage solutions, electric vehicle (EV) charging infrastructure, battery technologies, and renewable energy applications such as solar and wind power integration.

Cases:

- **Energy Data Centre**
- **Geothermal Energy and Drilling**
    - GA Drilling: Drilling and geothermal energy technology for carbon-free local energy sources.
- **Battery Storage and Electric Vehicle Charging**

  - InoHub Energy: Tailor-made commercial solutions for stationary battery storage with renewable sources.
  - InoBat: Advances battery technology for electric vehicles and energy storage.
  - Fuergy: Specialises in battery optimisation with their own battery storage system.
  - AgeVolt: Charging platform for electric cars.
  - GreenBat: Focuses on battery storage, photovoltaic power plants, and resource flexibility aggregation.
- **Hydropower and Renewable Energy**
  - SPEAR Hydro: Floating hydro power plant that provides clean electricity from river flow.
  - Greenlogy: Green energy and virtual green battery supplier.
- **Photovoltaic Solutions**
  - Sun Powered Systems
  - Enertec
- **Energy Management and Optimization**
  - Daitable: Smart energy management for industries.
  - eSYST: Developed software for energy optimization.
  - Emon.app: Tools for energy consumption management and control.
  - IPESOFT: Software solutions for industrial automation, energy management, and smart systems.
  - Ceelabs: Solutions for information gathering and SmartGrid network management.
- **Virtual Power Plants and Aggregation**
  - PowereX: Aggregator and virtual power plant operator.
  - GreenBat: Also involved in the aggregation of resource flexibility for energy network regulation.
- **Solar Resource Data and Forecasting**
  - Solargis: Develops high-precision solar resource data and forecasting tools.

Conclusion: evolution & current state

The evolution of Slovakia's energy system and its current state reflect a nation grappling with significant dependencies, structural inefficiencies, and the pressing need for modernization. Historically, Slovakia's energy system has been heavily reliant on imports, particularly from Russia, posing challenges in terms of energy security and geopolitical stability. The country's energy mix has been dominated by nuclear power, supplemented by biofuels, hydro, coal, oil, and natural gas, with minimal contributions from wind and solar energy. This composition highlights the critical need for diversification and the enhancement of renewable energy sources.

In response to these challenges, Slovakia has initiated several strategic plans and policies aimed at transforming its energy sector. These include the National Recovery and Resilience Plan, the Cohesion Policy and European Regional Development Fund, and the Just Transition Fund, all of which allocate substantial resources towards green transition initiatives. Key focus areas include the accelerated deployment of renewables, enhanced energy efficiency, and the development of sustainable transport and digital infrastructure. Despite these efforts, the energy sector faces significant hurdles such as high

energy intensity, limited progress in reducing greenhouse gas emissions, and an underdeveloped renewable energy sector.

Slovakia's innovation ecosystem in the energy sector is characterised by collaborative efforts between key national players, academic institutions, and a network of NGOs. This ecosystem has fostered several notable innovations, particularly in energy storage, electric vehicle infrastructure, and renewable energy applications. However, the innovation system is hampered by insufficient and inconsistent financing, brain drain, and immature technology transfer practices.

Moreover, the level of digitalization within Slovakia's energy sector remains insufficient. The adoption of advanced digital solutions such as Energy Management Systems (EMS) and Internet of Things (IoT) technologies is slow, particularly at the commercial and residential levels. The national grid lacks extensive smart grid enhancements, and the penetration of e-mobility infrastructure, including electric vehicle charging stations, is still low. Efforts to introduce Energy Data Centers (EDC) and improve digital skills are positive steps, but they need to be significantly scaled up to meet modern energy management needs.

The business environment and investment climate in Slovakia reveal a mixed picture. While the country has shown resilience to recent economic shocks and has made substantial commitments to green investments through EU structural funds, challenges remain. These include high inflation, energy prices, supply chain disruptions, and a need for modernization in energy infrastructure.

Cultural and attitudinal factors also play a significant role in shaping Slovakia's energy transition. A fragmented approach to entrepreneurship and innovation, combined with a risk-averse institutional mindset, has slowed progress. Nonetheless, initiatives such as the establishment of Digital Innovation Hubs and support for startups indicate a growing recognition of the need for a robust entrepreneurial ecosystem.

Slovakia's energy sector is at a critical juncture. The country has laid the groundwork for a transition to a more sustainable and diversified energy system through various strategic plans and investments. However, achieving these goals will require continued commitment to innovation, increased investment in renewable energy and energy efficiency, and a cultural shift towards embracing the green transition. By addressing these challenges, Slovakia can enhance its energy security, reduce its environmental impact, and foster a more resilient and sustainable energy future.

3.3.3 Programme/Project based Ecosystems

To our knowledge, there are no project-based energy ecosystems in Slovakia as of now. However, a non-profit "Climate needs you" (Klíma ťa potrebuje) has indicated their ambition to create their local energy hub. These efforts have not yet been translated into actionable steps, demonstrating that while these aspirations are present in Slovakia, the country does not yet present an optimal ground to kickstart such projects.

4. Ukraine

Country profile[36]:

Region: EUR

Income: High

Population (mn): 39,7

GDP, PPP$ (bn): 409.8

GDP per capita, PPP$: 42,132

Global Innovation Index, rank: 55

Total energy consumption per capita, kWh[37]: 16309

4.1 Energy Systems State and Challenges

The Ukrainian energy system is characterised by the diversified energy sources (Figure 8) and a declining energy consumption (Figure 9).

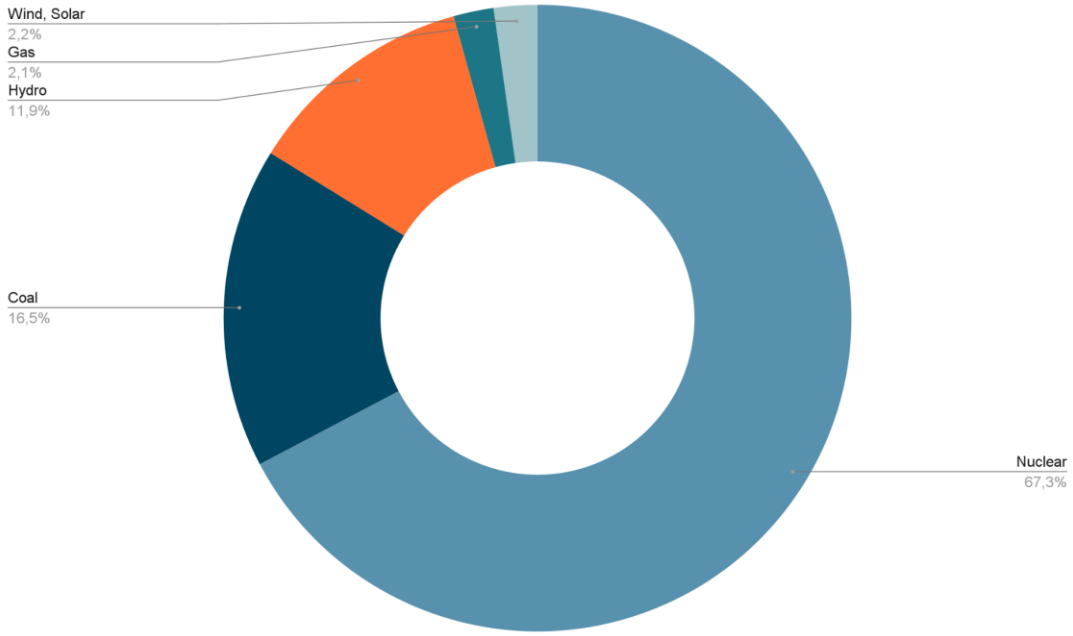

Figure 8: Energy generation in Ukraine by sources, 2024[38]

[36] https://www.wipo.int/edocs/pubdocs/en/wipo-pub-2000-2023-en-main-report-global-innovation-index-2023-16th-edition.pdf

[37] https://www.iea.org/countries/ukraine/energy-mix

[38] Statista, 2024

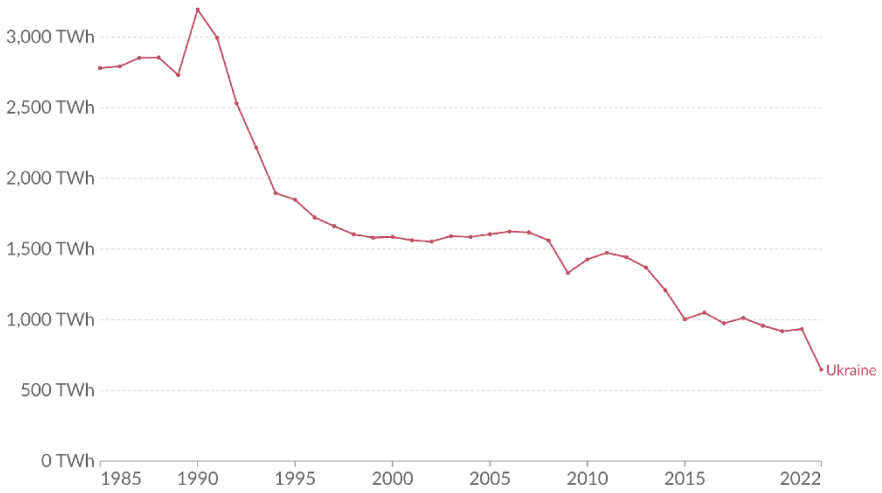

Figure 9: Primary Energy Consumption in Ukraine (1985-2022)[39]

As of February 2024, Ukraine held one of the highest shares of carbon-neutral generation in Europe - approximately 81,4% of the electricity was generated through nuclear, hydro, and renewable sources. After the full-scale Russian invasion in 2022, **Ukraine has lost ninety percent of its wind generation and a third of its solar capacity**. Thus, the production of "green" energy in the country has halved.

National strategic documents on energy sector development include:

1. ENERGY STRATEGY 2023-2050
2. Concept for the implementation of "smart grids" in Ukraine until 2035
3. The concept of the State Target Economic Program for Energy Modernization of Enterprises Producing Thermal Energy in State or Communal Ownership for the period up to 2030
4. The concept of implementing the state policy in the field of district heating, 2017
5. The State Target Economic Program for Energy Modernization of Water Supply and Wastewater Treatment Enterprises in State or Municipal Ownership till 2030

As a signatory of the Energy Community Treaty (2011), Ukraine is mandated to move towards renewable energy and energy efficiency,as well as committed to regular reporting on the progress. Following the Association Agreement with the EU (2014), Ukraine, among others, is also committed to:

- development and support of renewable energy;
- mechanism for joint implementation of the Kyoto Protocol to the UN Framework Convention;
- scientific and technical cooperation and information exchange for the development and improvement of technologies in the field of energy production, transportation, supply and final consumption, with special attention to energy-saving and environmentally friendly technologies.

Drivers of renewable energy transition in Ukraine include:

- **Incentivisation Model:** Adoption of the "feed-in-tariff" (FIT) model at a national level acted as a significant driver for RET implementation.
- **Global Trends and Cost Reduction:** The global trend of cost reduction per kilowatt of installed capacity and the "learning curve" effect significantly accelerated the adoption of RETs.

[39] U.S. Energy information Administration (2023); Energy Institute - Statistical Review of World Energy

Country challenges:

- **Dependence on Fossil Fuels:** Historically, Ukraine has heavily relied on fossil fuels like coal and natural gas for its energy needs. This dependency poses challenges in terms of sustainability, environmental impact, and supply security. Ukraine produces all fossil fuels (in 2018: 14.4 million tonnes of oil equivalent [Mtoe] of coal, 16.5 Mtoe of natural gas and 2.3 Mtoe of crude oil), but in quantities insufficient to meet total energy demand
- **Ageing Infrastructure:** The country's energy infrastructure, particularly in the power sector, is ageing and requires significant modernization and investment to enhance efficiency and reliability.
- **Political and Geopolitical Factors:** Energy supplies, particularly natural gas, have been influenced by geopolitical tensions, affecting the security and stability of the energy sector.
- **Energy Efficiency:** There is a need to improve energy efficiency across various sectors, including industry, transportation, and households, to reduce energy waste and optimise consumption.

The integration of Ukraine into the EU is the basis for further modernization and reforms in the energy sector. In Ukraine, there is recognition and a developed policy supporting the transition to digital green energy at both central and local levels.

The biggest challenge to the energy sector is active military action. According to World Bank estimates, the energy sector's losses due to active hostilities amount to $10.6 billion. The loss of more than 9.2 gigawatts of electricity by the Ukrainian power system creates serious challenges that cannot be overcome without the introduction of innovations, a generation distribution system, and a green transition.

Energy strategy of Ukraine for the period until 2050 states that a strategic goal is for the share of renewable energy sources to reach 30%.

Legislation stimulates projects for the production of electricity from renewable sources through the mechanism of the "green" tariff (Feed-In Tariff). This tariff is applied to facilities without capacity limitations that produce electricity from solar, wind, biomass, biogas, geothermal energy, and hydropower facilities with a capacity of up to 10 MW.

Support mechanism from the The National Commission, which Provides for State Regulation in the Spheres of Energy and Communal Services (NEURC) for producers of electricity from renewable energy sources in Ukraine:

- Purchase of produced electricity at the "green" tariff (Feed-In Tariff), which will not change until December 31, 2029.
- Sale of electricity by producers to the State Enterprise "Guaranteed Buyer" at the "green" tariff (Feed-In Tariff).
- Fulfilment of special obligations: reimbursement of the deficit associated with the green tariff.

4.2 Functioning Innovation Ecosystems

4.2.1 Science, Research and Innovation Systems

Despite the full-scale war, Ukraine continues to support and develop its science, research and innovation system and to set global trends.

Ukraine has the 55th rank among the 132 economies in the Global Innovation Index 2023 (GII). At the same time, Ukraine has the 3rd position in innovation in the Lower middle-income group. Ukraine performs better in innovation outputs than innovation inputs in 2023. This year Ukraine ranks 78th in innovation inputs. Ukraine ranks 42nd in innovation outputs. Ukraine produces more innovation outputs relative to its level of innovation investments. Ukraine ranks highest in Creative outputs (37th), Knowledge and technology outputs (45th), Human capital and research (47th) and Business sophistication (48th). At the same time Ukraine ranks lowest in Market sophistication (104th), Institutions (100th) and Infrastructure (77th).

Ukraine has a strong position in terms of the level of development of human capital and research, knowledge and technology outputs, business sophistication and creativity outputs, but the level of development of institutions, infrastructure and the market sophistication remains weak. In 2021, prior to the full-scale invasion, Ukraine was ranked 49th out of 132 countries in the Global Innovation Index. Over the past seven years, Ukraine has not significantly improved its position in the ranking, with its score in 2021 being lower than that of 2015. Among other measures, in 2019, Ukraine rethought the concept of a digital state and chose the mobile-first approach and launched the state superapp Diia. This has shaped the culture of digital transformation in Ukraine, and is influencing the whole world.

Formation and implementation of priorities in the field of science and innovation in Ukraine are regulated by four **laws**:

1. "On Scientific and Scientific-Technical Activities"
2. "On Innovation Activity",
3. "On Priority Branches of Science and Technology Development" and
4. "On Priority Directions of Innovation Activity in Ukraine"

The last two laws list the strategic priority directions for the development of science and technology and the development of innovation for the medium term.

There is no single strategy that determines the development of science in Ukraine. However, the Government of Ukraine approved several policy documents that address a number of strategic issues, among them – the Strategy for the Development of the Innovation Sector for the Period up to 2030 (approved by the order of the Cabinet of Ministers in 2019). The adoption in 2019 of, but it failed to have a significant effect in the field of innovation due to lack of resources for implementation, a lack of horizontal coordination between authorities and stakeholders, the Covid-19 pandemic, and a full-scale war[40].

[40] https://scienceatrisk.org/storage/lp/125/28ae32642520ad8022db551636b69c6de3bc0d4e.pdf

On December 14, 2023, the Ministry of Digital Transformation of Ukraine presented the **new vision of the "Innovation Development Strategy" of Ukraine until 2030**. For the stable innovative development of Ukraine, the Ministry of Digitization proposed a new management organisational structure: The Ministry of Digital will be responsible for strengthening coordination; Innovation Development Council — for discussion, preparation and approval of the strategy; Deputies for digital transformation (CDTO) in ministries — for the formation of innovative policies in various fields; CDTOs in the regions — for policy implementation in the regions; The State Agency for the Development of Innovations — for the implementation of the strategy and the search for investments in innovations.

Priority directions:
2024-2027 years
MedTech — development of medicine with the help of technologies
DefenseTech — military and defence technologies
2024–2030 years
AgriTech — agricultural technologies
Immersive technologies (XR)
2025–2035 years
AUV - unmanned technologies
BioTech — biological, technical and chemical sciences, the use of biology in other fields
GreenTech – "green" environmental projects
Transversal directions
Artificial Intelligence
Semiconductors
Cyber security
Fluid Economy
EdTech is an educational direction

One of the principles of the national economic strategy of Ukraine is decarbonization of the economy, which includes increasing energy efficiency, development of renewable energy sources, development of a circular economy and synchronisation with the "European Green Course" initiative.

As part of the Innovation Strategy 2030, the Ministry of Digitization proposes to create and expand:

- AI for Energy is a competence centre for the use of artificial intelligence for energy security, efficient dispatching and the development of digital grids;
- Power electronics — production of power electronics and semiconductors;
- "eSubsidy" is a digital program to prevent energy poverty and monetize subsidies;
- R&D centres — attracting to Ukraine R&D centres of leading global developers in the field of green technologies (LG Chem, ABB, Schneider Electric, Siemens, Hemlock Semiconductor, Enphase, Northvolt, Morrow, Sonnen and others)
- partnerships with MIT, CalTech, Frauenhofer Institute, Stanford University, Korea Advanced Institute of Science and Technology.

The institutional framework for research policy at national level includes:

1. **Verkhovna Rada of Ukraine**, which carries out state regulation in the field of scientific activities, approves the basic principles and directions of state policy in the field of scientific activities, priority areas of science and technology and national programmes of scientific and technical development of Ukraine.

2. **Committee of the Verkhovna Rada of Ukraine on Education, Science and Innovation**, which ensures the implementation of draft law work, preparation and preliminary consideration of issues in the field of science and innovation, performance of control functions.

3. **Cabinet of Ministers of Ukraine**, which ensures the implementation of state scientific and technical policy, development and strengthening of scientific and technical potential of Ukraine and other measures of state regulation and management in the field of scientific and technical activities.

4. **National Council of Ukraine for the Development of Science and Technology**, which is an advisory body established under the Cabinet of Ministers of Ukraine to ensure effective cooperation between representatives of the scientific community, executive bodies and the real sector of the economy in forming and implementing a unified state policy in the field of scientific and scientific-technical activities (established by the resolution of the Cabinet of Ministers of Ukraine, dated 5 April 2017 No. 226). The Council is headed by the Prime Minister of Ukraine.

The Council is composed of *two committees*:

a) ***the Scientific Committee***, which represents the interests of the scientific community and consists of its representatives – scientific leaders with outstanding scientific achievements, impeccable scientific reputation and trust among the scientific community;

b) ***the Administrative Committee***, which consists of representatives of central executive bodies, the National Academy of Sciences of Ukraine and national branch academies of sciences, regional (city) state administrations of regions where significant scientific potential are concentrated, state bodies responsible for science, large science-intensive enterprises, research institutions, universities, academies, institutes, innovation structures.

5. **Ministry of Education and Science of Ukraine** is the central body of executive power that ensures the formation and implementation of state policy in the field of scientific and scientific and technical activities

6. **Other central executive bodies in the field of scientific and scientific-technical activities** manage the scientific and scientific-technical activities of relevant industries, determine the directions of development of scientific and scientific-technological potential of relevant industries, direct and control the activities of scientific institutions belonging to the sphere of their management:

the Ministry of Finance of Ukraine, the Ministry of Economy of Ukraine, the Ministry of Justice of Ukraine, the Ministry of Internal Affairs of Ukraine, the Ministry of Defence of Ukraine, the Ministry of Energy of Ukraine, the Ministry of Agrarian Policy and Food of Ukraine, the Ministry of Communities and Territories Development the Ministry of Healthcare of Ukraine, the Ministry of Environmental Protection and Natural Resources of Ukraine, the Ministry of Social Policy of Ukraine, the Ministry of Culture and Information Policy of Ukraine, the Ministry of Youth and Sports of Ukraine, Antimonopoly Committee of Ukraine.

7. **National Academy of Sciences of Ukraine**, which is the highest scientific self-governing organisation of Ukraine that organises and conducts basic and applied research on major issues of natural, technical, social and human sciences.

8. **National branch Academies of Sciences** that are self-governing scientific organisations coordinating, organising and conducting research in relevant fields of science and technology:

a) the National Academy of Agrarian Sciences of Ukraine,

b) the National Academy of Medical Sciences of Ukraine,

c) the National Academy of Educational Sciences of Ukraine

d) the National Academy of Legal Sciences of Ukraine,

e) the National Academy of Arts of Ukraine.

9. **National Research Foundation of Ukraine**, which is a state budget institution whose main task is providing grant support for fundamental research in the field of natural, technical, social and human sciences, as well as applied research and scientific and technical (experimental) innovations in priority areas of science and technology.

10. **Local authorities** – local councils and local executive bodies that ensure the implementation of state targeted scientific and scientific-technical programmes, organise the development and implementation of regional (territorial) programmes of scientific and technical development, promote the development of infrastructure of scientific and scientific-technical activities of the region, involve relevant scientific institutions (with their consent) in order to solve the problems of scientific and technical development of the region

The institutional framework for innovation policy includes:

1. **Council for Innovation Development** is an interim advisory and consultative body of the Cabinet of Ministers of Ukraine, set up to study the issues related to the implementation of state policy in the sphere of developing innovations, ensuring efficient cooperation between the Cabinet of Ministers of Ukraine, executive authorities, civil society, economic entities and innovation activity entities to develop, organise, coordinate and implement measures, mechanisms and conditions for the innovative development of the domestic economy, creating the innovative infrastructure and implementing the reforms in the sphere of innovation activity.
2. **Ministry of Education and Science of Ukraine**, which ensures the development and implements the state policy in the spheres of education and science, scientific, scientific and technical activity, innovative activity in the mentioned spheres, transfer (transition) of technologies.
3. **Ministry of Economy of Ukraine**, which ensures the development and implements the state policy in the innovative activity sphere in the real sector of the economy.
4. **Ministry of Strategic Industries of Ukraine**, which ensures the development and implementation of the state industrial policy, state military and industrial policy, state policy in the sphere of government defence order, military-industrial complex, aircraft construction industry, and ensures the formation and implementation of the state policy in the sphere of space activity.

5. **Ministry of Digital Transformation of Ukraine**, which ensures the development and implements the state policy in the sphere of digital innovations and technologies.
6. **Other central executive bodies** that implement the state policy of innovative activity within their purview.
7. **Working group on innovative development of the economy** was set up by the President of Ukraine to develop the proposals regarding the following:

   a) top priority measures to develop the digital transformation of the economy and to introduce technological innovations into the industrial processes;
   b) directions of implementing the innovative projects to activate the most promising spheres of economic activity, to introduce novel approaches and standards of carrying out activities in relevant spheres;
   c) creating conditions for the implementation of innovative projects of top priority for the state and the development of technological companies.

The research infrastructure includes:

1. National Research Foundation of Ukraine;
2. Centres for Collective Use of Scientific Equipment (103 centres);
3. National Research Centres (10 centres);
4. State Key Laboratories;
5. Regional research centres (9 centres);
6. Objects that constitute national heritage (unique scientific objects (collections, information funds, research facilities and equipment, as well as reserves and arboretums, scientific landfills, etc.), which are of exceptional importance for domestic and world science).

The elements of innovation infrastructure include:

1. innovative business accelerators;
2. innovative business incubators;
3. innovation clusters;
4. innovation, science and technology parks;
5. innovation hubs;
6. start-ups and spin-off companies;
7. innovative technological platforms;
8. Ukrainian Startup Fund;
9. technology transfer centres;
10. centres for the implementation of the technological approach "Industry 4.0";
11. venture funds;
12. authorised bodies in the field of innovation;

13. financial and credit institutions in the field of innovation;
14. project management units (project offices), established at higher education institutions and research institutions.

40 **science parks** operate in Ukraine for the development of R&D activity in higher educational institutions and/or scientific organisations, efficient and reasonable use of available scientific potential, facilities and resources for commercialization of the results of scientific studies and their introduction both in domestic and international markets.

Ukraine develops **technology parks** (in general, 16 technology parks were established in Ukraine). Their aim is comprehensive organisation of science-based production via maximal promotion of the creation and introduction of new technologies and stimulating the development of the specialists' creative capacity. Concentrating scientific, industrial, and financial resources, technology parks ensure the renewal of the complete life cycle of innovations: a study – an elaboration – an introduction – large scale production release of science-based high-technology products, competitive in international markets.

Pursuant to the Resolution of the Cabinet of Ministers of Ukraine "On Promoting the Implementation of the Technological Approach "Industry 4.0" in Ukraine" No. 750 dated July 21, 2021, the implementation of Industry 4.0 in Ukraine is ensured by the **Industry 4.0 implementation centres**. The main tasks of these centres are to popularise Industry 4.0 in the real sector of the economy, to promote the development of cooperation between enterprises, institutions and organisations, implementing Industry 4.0.

Financial support for scientific and scientific-technical activities in Ukraine is provided at the expense of state and local budgets, institutions, organisations and enterprises, domestic and foreign customers, grants and other sources not prohibited by law.

Grant support is provided free of charge and on a non-refundable basis. According to the legislation, it can be provided by the central executive body that ensures the formation and implementation of state policy in the field of scientific and scientific-technical activities, other central executive bodies, which govern budget research institutions, universities, academies, institutes, National Academy Sciences of Ukraine, National Branch Academies of Sciences and National Research Foundation of Ukraine.

Today, the main provider of grant support is the **National Research Foundation of Ukraine**, which ensures grant support for:

1) fundamental research in the field of natural, technical, social sciences and humanities;

2) applied scientific research and scientific-technical (experimental) developments in priority areas of science and technology.

Ukrainian Startup Fund (USF) was established on the initiative of the Government of Ukraine (Order of the Cabinet of Ministers of Ukraine No 895-r dated November 7, 2018). USF is a state-owned fund that provides non-refundable and non-equity grants for pre-seed and seed-stage start-ups engaging in the following activities: artificial intelligence (AI), augmented reality (AR / VR), big data (BigData), blockchain, educational technology (EdTech), lifestyle, energy and ecology, financial technology (Fintech/legaltech), e-government, healthcare, media and advertising, retail, industry, security. The mission of USF is to

promote the creation and development of technology start-ups in Ukraine at an early stage in order to increase their global competitiveness. USF provides financial support to start-ups in the early stages in the form of grants, as well as creates additional opportunities for startups to incubate, accelerate, and receive other types of support.

In the past few years, Ukraine has been taking significant steps to improve its business environment and create favourable conditions for attracting, inter alia, R&D investments. In 2019 the Ukrainian Government created the **Ministry of Digital Transformation**, which has the strategy to digitise Ukraine and in particular to develop the IT industry in Ukraine. On top, there is a platform, Ukrainian IT association, which creates a dialogue between IT companies in Ukraine and the Government. Recent achievements of Ukrainian IT associates include the simplification of the procedure for importing prototypes of equipment for R&D purposes to Ukraine and the simplification of the procedure for opening private individual tax numbers for foreigners.

In 2021, Ukraine has presented a **new legal regime for IT business called "Diia City"** which provides for tax benefits, flexible employment regulations, application of common law's best practices regarding venture capital investments etc. for a period of not less than 25 years. Companies engaged in R&D in IT and telecom are eligible to become a "Diia City" resident.

Science and research in Ukraine are conducted at 158 research institutions and 43 R&D enterprises of the National Academy of Science of Ukraine, with 19 institutions at 2 departments of NASU of energy issues, but many more are conducting energy related research at institutions of other departments (physics, materials science, chemistry etc). There is also research on innovation, IP, science development etc. conducted at the economics department of NASU.
There are 314 higher educational establishments in Ukraine, 68 higher education institutions provide training in electrical engineering that include the following areas:

- electrical power engineering, electrotechnics
- energy machine building
- nuclear power engineering
- thermal power engineering
- renewable energy sources and hydropower.

4.2.2 Business environment and Investment Climate

Economic Predictability	Assessing the business environment and investment climate in Ukraine is challenging due to the limited distribution of official information during wartime conditions. Consequently, some estimates rely on forecasted and expert data rather than official sources. Ukraine, until 2022, was little known to foreign investors and remained underinvested. Development mainly occurred through internal investment resources. However, since February 24, 2022, due to a full-scale invasion, Ukraine's investment attractiveness index has plummeted. The war is severely impacting human and physical capital, with large-scale loss of life, drop in living standards, rise in poverty, and damage to infrastructure. The military aggression of the Russian Federation against Ukraine has become the foremost factor negatively impacting the investment climate, with corruption ranking second, and a weak judicial system third. In 2021, Ukraine's GDP was $200.09 billion USD, with a GDP per capita of $4,835.6 USD. In 2023, the real GDP of Ukraine grew by 5-5.5%, according to various estimates. It is 160.50 billion USD. This represents a recovery from the sharp decline of 28.8% experienced in 2022. Despite this rebound, the GDP remains approximately a quarter smaller than it was in 2021[41]. High-tech exports represent only 5.9% of Ukraine's manufactured exports, compared to 12.9% for the lower-middle income countries, and 18.2% of OECD[42] members' exports in 2020. The low-tech structure of the economy has limited the extent of innovation activities in industry and consequently the demand for domestic science and technology, as enterprises prefer to purchase standard ready-made solutions, further limiting incentives for business-academia partnerships. Numerous initiatives were in place prior to the war, including science parks, technology parks, industrial parks, technology transfer centres, innovation centres, centres for intellectual property commercialisation and innovative incubators. However, the overall impact of these structures on the overall innovation performance remains below expectations, and some are not operational due to a lack of funding or insufficient innovative projects.
Financial market	The International Monetary Fund (IMF)[43] has noted that despite Russia's war in Ukraine, macroeconomic indicators have surpassed expectations, leading to an upward revision in the growth outlook. This economic resilience has translated into improved growth outcomes, sustained disinflation, and stability in the foreign exchange market, particularly following the National Bank of Ukraine's departure from the exchange rate peg, supported by robust reserves. The baseline projection for real

[41] The World Bank Data base. https://www.worldbank.org/en/country/ukraine/overview

[42] OECD. Building back a better innovation ecosystem in Ukraine. 04 November 2022. https://www.oecd.org/ukraine-hub/policy-responses/building-back-a-better-innovation-ecosystem-in-ukraine-85a624f6/

[43] Ukraine: 2023 Article IV Consultation, Second Review Under the Extended Arrangement Under the Extended Fund Facility, and Requests for Modification of Performance Criteria and a Waiver of Nonobservance of Performance Criterion-Press Release; Staff Report; and Statement by the Executive Director for Ukraine https://www.imf.org/en/Publications/CR/Issues/2023/12/11/Ukraine-2023-Article-IV-Consultation-Second-Review-Under-the-Extended-Arrangement-Under-the-542297

	GDP growth in 2023 has been adjusted upward to 4.5 percent. However, growth is anticipated to moderate in 2024 to a range of 3–4 percent as the conflict persists. Ukraine entered 2023 with record-high inflation, primarily driven by the war and the printing of the hryvnia to cover military expenses. However, inflation was brought under control throughout the year: consistent inflows of foreign aid enabled the government to cease monetary financing (via hryvnia emission) of the budget, while successful harvests contributed to lowering food prices. By December 2023, inflation had reached 5.1%, nearly returning to the pre-war inflation target of 5%. However, sizable reliance on external financing will continue in 2024 given war-related fiscal strains. According to estimates from the IMF[44], Ukrainian financial system remains stable and liquid, thanks to extensive emergency measures. The Ukrainian business and financial sector continues to adapt to operating within a war-affected environment. Despite the challenges, banks have experienced further inflows of client deposits, both retail and corporate. Additionally, the share of term retail deposits has increased due to measures implemented by the National Bank of Ukraine (NBU), thereby mitigating potential liquidity risks for banks. Corporate lending in the hryvnia has been gradually recovering since June 2023, primarily due to government support programs such as "5-7-9". Moreover, lending outside of these programs is also witnessing an uptick. Income generated from investments in government and NBU securities, as well as from corporate loan portfolios, has significantly contributed to the sector's interest income. Banks have maintained high operational efficiency and minimised provisioning costs. Consequently, the sector has recorded higher profits, totaling over UAH 120 billion in the initial months of 2023. Innovations are mostly financed by the company investments (87,7%) with 3,9% coming from the state budget and 0,3% from the foreign investments[45]. Analytics estimate[46] that Ukrainian startups were able to raise about $550 mln of investments in rounds Seed, A, B and growth and demonstrated a positive trend during the last 5 years prior to the war. In 2021 54% of the investments on Seed round were coming from Ukrainian investors, while on round A the leading position was taken by foreign players (89% in 2020 and 77% in 2021). In 2022, bank profits declined due to reduced demand for loans and banking services overall, along with asset revaluation stemming from hostilities and occupation. Conversely, banks experienced significant success in 2023, attributed to monetary policies offering high rates on certificates of deposit. To fund state defence spending, a temporary increase in the bank income tax was implemented: 50% in 2023 and 25% in 2024-2025.

[44] Ukraine: 2023 Article IV Consultation, Second Review Under the Extended Arrangement Under the Extended Fund Facility, and Requests for Modification of Performance Criteria and a Waiver of Nonobservance of Performance Criterion-Press Release; Staff Report; and Statement by the Executive Director for Ukraine https://www.imf.org/en/Publications/CR/Issues/2023/12/11/Ukraine-2023-Article-IV-Consultation-Second-Review-Under-the-Extended-Arrangement-Under-the-542297

[45] Center for Economic Recovery, CIVITTA, World Bank, World Economic Forum, Ministry of Education, Ukrainian Institute of Scientific and Technical Expertise and Information, Ministry of Finance

[46] Center for Economic Recovery, CIVITTA, PUSB, UVCA, USF, World Ban, Forbes, AVentures

Legal and Political Settings	In 2022, several government initiatives were approved to support businesses and ensure economic stability. The government proposed the following solutions: - Natural persons-entrepreneurs in the I and II groups are exempt from paying a single social contribution during martial law and for one year following its end. - Enterprises and natural persons-entrepreneurs in the III group are exempt from paying a single social contribution for employees who have joined the Armed Forces or other armed formations (including territorial defense). This fee will be covered by the state. - Tax payments are postponed for all enterprises that are unable to meet their obligations. - The introduction of cash registers for all individual entrepreneurs is postponed. - All market and consumer supervision measures, except for price regulation and control, are cancelled. A moratorium on all types of business inspections has already been implemented. The rule of law in Ukraine is unreliable and suboptimal. There is a divergence between customary law and formal law. In such situations, the principle of the rule of law fails, and citizens resort to bribing public officials to continue their traditional practices, which differ from the written rules. Meanwhile, state bodies develop laws and regulations that are either impossible or extremely difficult to implement according to legal procedures. Due to dysfunctional law enforcement, there is no effective way to enforce written rules when they conflict with customary law[47]. However, in 2024, discussions began about increasing taxes and the military levy due to a state budget deficit. Preferential taxation has been introduced for certain goods, such as generators. Overall, while these measures help businesses operate during wartime, they may limit the potential for introducing innovations.
Labour market, Human resources and skills	In the initial month of the full-scale war, mass layoffs and a slowdown in business activity led to an influx of new workers into the labour market, surpassing the capacity of employers to accommodate them. Throughout 2022, the dynamics of the labour market stabilised, and by 2023, the ratio of new job seekers to new vacancies had returned to the level of 2021. Ukraine possesses significant development potential and boasts a high Human Development Index[48] (HDI). According to the UN Population Fund[49], as of 2023, Ukraine

[47] Dubrovsky V., Bojarchuk V. Analytical Report: Sustainable Economics Growth in Suboptimal Conditions Institutions in Ukraine https://case-ukraine.com.ua/content/uploads/2024/01/CIPE-Position-Paper-2024-01-07-THIS-ONE-FINAL-UA-3.pdf

[48] The Human Development Index (HDI) is a summary measure of average achievement in key dimensions of human development: a long and healthy life, being knowledgeable and having a decent standard of living. The HDI is the geometric mean of normalised indices for each of the three dimensions. https://hdr.undp.org/data-center/human-development-index#/indices/HDI

[49] https://pdp.unfpa.org/?_ga=2.45627367.2118163010.1711235511-113925170.1711235511&_gac=1.263003390.1711235511.Cj0KCQjw-_mvBhDwARIsAA-Q0Q6sWqBNXy7hqmKeWdlME1Mi8I97C5KkII7zPlRvWpq4mH-oe4Lwk1kaAhgeEALw_wcB&country=804&data_id=dataSource_8-6%3A231%2CdataSource_8-1%3A2%2B10%2B11&page=Explore-Indicators

	was home to 36.7 million people, with over 20% being individuals over 65 years of age and another 15.2% being children under 14 years old. It can be observed that over the last 10 years, the rate of development of human capital in Ukraine has surpassed the global average. Migration resulting from the war has not been able to significantly diminish it. Ukraine has the 100 rank from 193 countries in terms of HDI. As of the end of September 2023, there are approximately 6.3 million Ukrainian migrants, with 4.2 million individuals holding temporary protection status in the EU. Among them, about 3.7 million are registered as internally displaced persons (IDPs), with their adjustment to the wartime circumstances intensifying. According to different estimates, 63 percent of migrants residing abroad express a willingness to return to Ukraine, contingent upon improvements in economic conditions, security, and housing. In the Global Talent Competitiveness Index 2023[50] rankings, Ukraine is placed 64th in the world and 36th in Europe. Throughout 2023, the trend of a steady decline in unemployment persisted. However, by the end of the year, unemployment remained one and a half to two times higher than in early 2022, before the full-scale invasion. The number of vacancies in the labour market steadily recovered in 2023 but has not yet reached the level of 2021. Conversely, the dynamics of job seekers were negative, indicating that labour shortage remains a significant obstacle to business activity. Only 16% of Ukrainian companies are considered innovative, defined as the introduction of a new product or process to the market or within their enterprise, compared to the EU average of 49%. Production processes in Ukraine rely on outdated technologies, resulting in high energy intensity per $1 of GDP, one of the highest in the world, amounting to 0.919 tons of energy in oil equivalent in 2020. Labour productivity in Ukraine ranks among the lowest in Europe, being three times lower than that in neighbouring Poland and Hungary. This can be attributed to the low-tech development of the Ukrainian economy, with R&D expenditure barely reaching 0.95% of GDP, which is 3–4 times less than in neighbouring EU countries. In 2020, exports of high-tech products were relatively weak, accounting for only 5.99% of total industrial exports, significantly lower than the EU average of 16% (Poland — 9.99%, Estonia — 20.95%).
Infrastructure	According to the World Competitiveness Yearbook 2021 by the Institute of Management Development (IMD), Ukraine holds the 54th position in the global competitiveness ranking. This ranking is derived from an analysis of the performance of 63 surveyed countries across 333 categories. Two-thirds of these benchmarks rely on statistical data, while one-third reflects the opinions of entrepreneurs. Ukraine ranks 54th in economic indicators and 53rd in Government efficiency. Additionally, it holds the 50th position in terms of business performance and infrastructure. It's worth noting that due to the onset of full-scale military operations within Ukraine's territory, the Institute of Management Development has excluded it from its rating[51].

[50] INSEAD (2023): The Global Talent Competitiveness Index 2023: What a Difference Ten Years Make What to Expect for the Next Decade Fontainebleau, France.

[51] https://www.imd.org/centers/wcc/world-competitiveness-center/rankings/world-competitiveness-ranking/

	The European Business Association (EBA)[52] evaluates Ukraine's Investment Attractiveness Index (IAI) through a survey, averaging five aspects of the investment climate. In 2023, the composite indicator of Ukraine's Investment Attractiveness Index slightly declined to 2.44 points out of a possible 5 (compared to 2.48 points in the second half of 2022). Among the directors surveyed, 84% from member companies of the Association perceive the investment climate as unfavourable. However, the proportion of those who find it extremely unfavourable decreased from 37% to 24%. 7% of top managers have a neutral view on the current investment climate, while another 9% consider it rather favourable. Despite the ongoing war, 32% believe that Ukraine remains profitable for new investors (compared to 17% a year ago). Furthermore, 57% of surveyed companies already present in the Ukrainian market intend to invest further during the conflict, with 79% expressing readiness to participate in the reconstruction process. Assessment of the investment climate's dynamics for the previous year remains cautious. Nearly half of the respondents, 48%, note a deterioration, while 39% see no significant changes, and 13% perceive an improvement. Looking ahead, 38% anticipate further deterioration over the next six months, while 48% expect no significant changes. However, 14% of top managers predict an improvement in the situation in the first half of 2024. Russia's war against Ukraine continues to be the foremost negative factor impacting the investment climate, followed by corruption and a weak judicial system. Conversely, business leaders positively acknowledge Ukraine's candidacy for EU membership, deregulation efforts, and the digitization of public services as favourable changes. Ukrainian businesses are facing problems due to the destruction of business infrastructure as a result of military operations and complicated logistics. In particular, the destruction of energy infrastructure has led to widespread power outages, necessitating the purchase of generators for business operations. This, in turn, has caused an increase in the prices of goods and services. The total amount of direct documented damages inflicted upon Ukraine's infrastructure due to the full-scale invasion by Russia as of January 2024 stands at $155 billion (at replacement cost). This estimate also takes into account the damage due to the explosion of the Kakhovka Hydroelectric Power Station (HPS) dam caused by the actions of the Russian Federation to Ukraine in June 2023.[53] As of the beginning of 2024, the damage to infrastructure has reached $36.8 billion, and the direct damages to industry and businesses have already reached $13.1 billion. According to the latest data, 78 small, medium, and large private enterprises, as well as 348 state-owned enterprises, have been destroyed or damaged. Due to hostilities, the direct damages from the destroyed infrastructure of the energy sector continue to grow, reaching up to $9 billion. In the agro-industrial complex, damages amount to $8.7 billion. Additionally, as of the beginning of this year, direct

[52] https://eba.com.ua/en/research/doslidzhennya-ta-analityka/

[53] https://kse.ua/about-the-school/news/155-billion-the-total-amount-of-damages-caused-to-ukraine-s-infrastructure-due-to-the-war-as-of-january-2024/

	damages in the areas of housing and public utilities total $4.5 billion, and healthcare has seen an increase of another $1.4 billion, bringing the total to $3.1 billion[54] According to preliminary estimates, in general, as a result of hostilities, 25.4 thousand km of roads and 344 bridges and overpasses of state, local or communal importance were destroyed[55]. In the energy sector, electricity production and transmission have suffered the most from Russian aggression. Between October 2022 and February 2023, the Russian Federation carried out targeted and large-scale attacks on facilities responsible for the production, transmission, and distribution of electricity. Following these attacks, regular and targeted shelling of energy infrastructure in frontline regions continued. The estimated total damages to these facilities exceed $7.4 billion. Direct losses for thermal power generation are estimated at $2.6 billion for thermal power plants (TPPs) and $320 million for combined heat and power plants (CHPs). Direct damages to hydroelectric power plants and hydroaccumulators (GAES) are currently estimated at $1.1 billion. In early June 2023, the Russians blew up and completely destroyed the Kakhovskaya HPP, with direct damages estimated at $586 million. The cost of constructing a new HPP of similar capacity is expected to be about $1 billion. Additionally, territories occupied by the Russian Federation since February 24, 2022, include the Vugleghirska, Zaporizhzhya, and Luhansk TPPs, as well as the Kurakhivska and Slovyanska TPPs, which are regularly attacked due to their proximity to the front line. Producers of electricity from renewable sources (RES) also suffer significant losses. According to the Energy Charter Secretariat, 13% of solar generation capacity is located in occupied territories, with 8% damaged or destroyed. About 80% of wind generation capacity is in occupied areas, with some damaged due to shelling. Additionally, 2% of bioenergy capacities are under occupation, and at least 4 biogas plants have been destroyed. The KSHE team estimates direct losses for RES producers (excluding large HPPs and GAES) at $220 million[56].

Table 7: Business environment and Investment Climate in Ukraine

[54] https://kse.ua/about-the-school/news/155-billion-the-total-amount-of-damages-caused-to-ukraine-s-infrastructure-due-to-the-war-as-of-january-2024/

[55] https://kse.ua/wp-content/uploads/2024/04/01.01.24_Damages_Report.pdf

[56] https://kse.ua/wp-content/uploads/2024/04/01.01.24_Damages_Report.pdf

4.2.3 Culture and Attitudes

Ukraine boasts a strong **entrepreneurial culture**, with startups flourishing actively. Interestingly, during times of war, innovative activity and startup initiatives have surged. The birth rate of startups has been notably higher during wartime, showcasing a heightened level of adaptability and flexibility in entrepreneurial activity.

At the same time, entrepreneurs identify the primary risks impeding their operations as staff mobilisation, potential power outages, employee departures abroad, and loss of contacts[57]. A survey conducted among businesses and startups revealed that the war is generating new possibility, driven by heightened needs for high-tech products and accelerated integration into the international business community[58]. In 2023, Ukraine was the second country in CEE region in terms of Enterprise value (EUR28B, after Poland), percentage of funded startups that become unicorns (5,3%, after Croatia)[59]. VC investments raised by startups in Kyiv in 2023 accounted for EUR 101M[60].

Directing efforts towards creating benefits for society is associated with the concept of **social entrepreneurship**, which seeks innovative solutions to environmental, social, or cultural issues.

The research from Gradus[61] indicates that 44% of Ukrainians consider whether a business supports the army when making purchasing decisions, while 21% value the volunteering efforts of a company's employees. Ukrainian businesses themselves recognize the importance of incorporating a social mission. According to the same survey, 84% of Ukrainian enterprises are actively engaged in addressing social issues.

Furthermore, an increasing number of international organisations are currently fostering the growth of social entrepreneurship in Ukraine through financial, educational, and technical support. Recognizing the limitations of state institutional and financial resources in addressing pressing social challenges, international technical assistance projects now play a pivotal role in this area. Social entrepreneurship has proven to be an effective mechanism for addressing social problems within communities.

Country still lacks success stories of **quadruple helix cooperation**. Though examples of effective joint projects between academia and business exist, there are still sufficient barriers for innovative solutions to be implemented and for successful public-private partnership to be launched. On the other hand, Ukraine is moving towards decentralising its energy sector due to severe infrastructure damage. Local communities and individual consumers are investing in alternative energy solutions to achieve energy independence, which helps to expand and scale existing modern solutions.

[57] https://gradus.app/uk/open-reports/
[58] https://gradus.app/uk/open-reports/
[59] https://dealroom.co/uploaded/2024/03/Dealroom-CEE-Report-2024-Uniqa-Cogito.pdf?x67760
[60] https://dealroom.co/uploaded/2024/03/Dealroom-CEE-Report-2024-Uniqa-Cogito.pdf?x67760
[61] https://gradus.app/uk/open-reports/

4.3 Ecosystem descriptions

4.3.1 Regional Ecosystems

Kyiv region ecosystem: energy efficiency and alternative energy as an Smart-specialisation strategy

At the regional level, innovation policy in Ukraine was to be implemented mainly through smart specialisation strategies. The implementation of these strategies has been suspended in many regions due to lack of funding, and their relevance has sometimes been lost, especially on the former occupied territories or those severely damaged. However, in August 2023, a Cabinet of Ministers of Ukraine introduced a new procedure for the development of regional strategies, where smart specialisation remained a mandatory component.

Work to join regions of Ukraine to the European Smart Specialization Platform (S3 Platform) is ongoing. **15 regions** have already joined the **the European Smart Specialization Platform** (S3 Platform): Cherkasy, Chernihiv, Donetsk, Ivano-Frankivsk, Kharkiv, Khmelnytskyi, Kyiv, Kirovohrad, Luhansk, Lviv, Poltava, Rivne,Ternopil, Vinnytsya and Zakarpattia regions. However, Kyiv Region is the only one that has indicated Development of energy-efficient solutions based on alternative energy sources as a smart specialisation priority. It covers the following industries:

- Production of steam boilers.
- Production of other general-purpose machinery and equipment.
- Production of machinery and equipment for agriculture and forestry.
- Supply of electricity, gas, steam and air conditioning.

Kyiv region ranks sixth in the country in terms of the number of innovatively active industrial enterprises. There are 41 innovatively active enterprises operating in the Kyiv region. They introduce new or significantly improved products to the markets. Before the Russian invasion, the total volume of products sold amounted to UAH 990.5 million. More than 77% of this amount came from exports. This is about UAH 766.9 million[62]. The share of regional employment in the field of "Production, transmission and distribution of electricity" is 3.5%. This is the highest rate among the industries that occupy leading positions in the regional economy in terms of innovation. 27.3% of all boiler houses in the Kyiv region run on alternative fuels[63]. Therefore, one of the promising areas was the creation of the **Kyiv energy cluster** for the development of energy-efficient solutions for the region's transition to green energy[64].

Kyiv's Region Innovation Ecosystem related to the energy sector is formed around research and higher education institutions, large and middle corporate players, local utility companies, energy-related

[62] https://investkyivregion.gov.ua/en/pro-oblast/promyslovyj-potentsial/
[63] The second panel discussion, held with the representatives of territorial communities of the Kyiv region, business, scientific institutions and public organisations that are interested in establishing a dialogue between key stakeholders of the region in the field of alternative energy.
[64] https://drive.google.com/file/d/1dgOdSpSEvcfMFkM9-SG7fpo6zG2qLhQw/view?usp=sharing

clusters, facilitators and green energy incubators. These ecosystems evolve through continuous collaboration between businesses, research institutions, and government agencies. The region also has its specific investment advantages.

The largest market in Ukraine

- Annual retail trade turnover is over **83.0 billion hryvnias**
- Retail trade turnover increased by **20 – 25 %** over the past 3 years.
- Great potential for the startups, small and medium-sized businesses development. More than **20 thousand** small and medium-sized enterprises operate in the region.
- **397** objects of infrastructure to support enterprises.

Best logistics conditions in Ukraine

- The central location of the region ensures efficient deliveries throughout the country and exports of goods to the EU and around the world.
- 4-6 hours away from the largest cities of Ukraine.
- 6 hours away from the EU border.
- 4 hours away from the international port in Odesa.

Developed infrastructure

- **1** Boryspil International Airport.
- **2** international cargo airports.
- **3** international transport corridors, **8 600 km** of roads and highways in total.
- **3** railway junctions (Kyiv, Fastiv, Mironivka) with **798 km** of railway tracks.
- **1** river port (river transshipment terminal “Pereiaslavskyi”).

Skilled workforce and a well-developed education system

- **0,8 million** people of skilled workforce.
- Population has grown by **3 %** due to internal migration over the past 4 years.
- One of the lowest unemployment rates - 6,6 % (2nd place in Ukraine).
- Powerful educational base: 29 colleges and universities and 28 vocational schools.

Favourable conditions for agriculture

- **1st place** by the number of pigs.
- **1st place** by the output of egg production.
- **2nd place** by sugar beet harvesting.
- **2nd place** by the number of poultry.
- **3rd place** by wheat harvesting.
- **4th place** by potato harvesting.
- **4th place** by the number of animals sold for slaughter (meat production).

Favourable business climate

- Communities are business-friendly and offer investors support and tax breaks; regional management is committed to developing the local economy and supporting investors.
- **10** registered industrial parks.
- About **174 thousand** people are involved in the production sector.
- **22.9 thousand hectares** for industrial purposes.

Figure 10: Companies and investors who chose Kyiv region

Ukrainian company **UFuture** is one of the largest players in the region, which includes the ecosystem of partners, investors and talents who work in the the fields of infrastructure, industry, renewable energy, pharmaceuticals and IT, as well as engages in IMPACT investments. UFuture supports numerous social projects in fields of education and economics to boost Ukraine's progress and global competitiveness, investing in education and innovative thinking to help people foster their potential and fuel passion for changing the world for the better. The company actively invests in new business and impact projects, including UNIT.City innovation parks in Kyiv and Kharkiv, LvivTech.City in Lviv, Bila Tserkva Industrial Park, Unit School of Business, INDAX production accelerator (see table below).

UNIT.CITY INNOVATION PARK **unit.city**	UNIT.City is Ukraine's first innovation park. It is one of the biggest platforms merging exceptional infrastructure and innovation ecosystems for IT and technology companies in central and eastern Europe (CEE). Located in Kyiv, UNIT.City sits on 25ha 6km from the city centre and forms an entire city block of mix-use real estate: offices, residential properties, innovative educational institutions, R&D centres, VR and AR laboratories, and 3D-printing and additive manufacturing facilities. When completed, UNIT.City will have around 860,000m2 of property that will accommodate up to 30,000 tenants, students, and residents. UNIT.City has been in high demand among well-established IT and technology companies, startups, creative firms, and even traditional corporations. The park already attracted such prominent tenants as Snapchat, DTEK Academy and Syngenta. UNIT.City provides space for seminars, meet-ups and conferences. The park offers its tenants a package of additional business development services, such as

	assistance in commercialization and fundraising, counselling and legal services, coaching, mentoring and accelerating programs, and prototyping laboratories. UNIT.City's mission is to create a unique innovation platform, where advanced companies, start-ups and mavens get an opportunity to cross paths and work together ramping up their growth and honing quality of their products and services.
BILA TSERKVA INDUSTRIAL PARK **ip-bt.com**	Bila Tserkva Industrial Park (IP) is a large investment project aimed at creating infrastructure and conditions for the sustainable industrial development of Ukraine. The park offers industrial land with all the engineering infrastructure and ready-made modern production, logistics and storage facilities for rent or purchase. Knowledge and significant experience in the development of industrial real estate allow the park team to provide the client with a range of services for efficient production. The key difference between the industrial park is its focus on creating ecosystems and clusters (production, logistics, others). The value of this approach for the customer is to establish supply chains, reduce order execution time and reduce production costs. The total area of Bila Tserkva Industrial Park is over 70 ha. The project provides for the construction of industrial and warehouse facilities with a total area of over 235.4 thousand square meters for 30 residents, as well as the creation of more than four thousand jobs and attracting $250 million. As of the beginning of 2020, six companies are residents of Bila Tserkva Industrial Park. The industrial park is located at a distance of 75 km from Kyiv, in the city of Bila Tserkva. The presence of an airfield, two railway stations and an international highway creates convenient logistics and allows easy access to the country's largest markets. Bila Tserkva, with a population of over 200,000, has cheap and skilled labour. The city's labour market exceeds 150,000 specialists and technicians, of whom 9,000 are unemployed (according to the ILO methodology). The majority of the city's population has received higher and secondary special education. More than 12 thousand people study in 16 vocational schools and universities of the city.
PLANK ELECTROTECHNICwww.plank.ua	Plank Electrotechnic is the first Ukrainian manufacturer of modern electrotechnical systems with the full production cycle. Production facilities are located in the city of Bila Tserkva on the territory of the Bila Tserkva Industrial Park. The products that combine wide functionality, modern design, innovation and European quality. The main technological process is the injection of halogen-free composite and polymeric dielectrics with flame retardants. The same products do not support combustion. All products are made exclusively in Ukraine.
UDP RENEWABLES **udpr.com.ua**	UDP Renewables is a Ukrainian renewable energy investment and development company. The company develops investment opportunities and forges strong and sustainable partnerships with multiple stakeholders, all to open the Ukrainian market to the global players, providing them with sufficient reliability and safety.

	UDP Renewables develops projects on a turn-key basis, which includes legal and technical due diligence of land plots, interconnections and land status reclaim, also project design, development of technical documentation, obtaining of feed-in tariff, EPC and O&M. With diversification in type of renewable power generation and geography, by 2022 UDP Renewables strives to become one of the largest producers of clean energy in Ukraine, with a total capacity of more than 300 MW.
UCODE IT ACADEMY **www.ucode.world**	ucode IT academy is a product IT company in the field of EduTech, founded by the holding company UFuture and InSoft Partners for the purpose of high-quality training of industry specialists. The academy offers affordable 24/7 hybrid learning with an offline format on the campus of the academy on the territory of the UNIT.City innovation park and online with worldwide access for future Ukrainian developers and programmers. At the academy, students study programming languages C, C++, Java, JavaScript, PHP, Python. Mark Zuckerberg wrote Facebook on them, Sony developed software for the Playstation, and Blizzard made the game World of WarCraft. During the programs, students master the skills of IT engineers and work in teams — write code and check each other's tasks with the help of mentors from partner companies and ucode team. Additionally, students' tasks are checked by the error-free Oracle system. Training in ucode also includes lectures by experts from companies such as Ajax System, Ubisoft, ITernal Group, CISCO and others, workshops, networking and a variety of leisure activities. A feature of ucode IT academy is the first in Ukraine implementation of an innovative methodology, which consists of Challenge Based Learning (CBL) and a peer-to-peer approach. Developer teams of iPhone, Mac OS, AppStore and others study behind it. IoT/GameDev world from Ajax System and Ubisoft, DevOps world from CISCO and Full Stack world from ITernal Group are currently available at the academy. After graduation, ucode helps with employment — currently, more than 10 thousand programmers work in the business of the academy's partners.
INDAX PRODUCTION ACCELERATOR **www.indax.com.ua**	The INDAX production accelerator is a system platform for supporting and scaling small and medium-sized businesses in the industrial sector. INDAX's mission is to develop Ukraine's small and medium-sized manufacturing business through investments and partnerships by supporting promising Ukrainian companies that are ready to produce quality goods. "The accelerator scales production projects and builds plants together with the Bila Tserkva industrial park. We think on a global scale because Ukraine can create a competitive product not only for import substitution," said Natalia Kalinkina, CEO of INDAX. INDAX offers entrepreneurs an analysis of the company's business and activities through the assessment of its financial model, production efficiency, product portfolio, cost structure, and competitiveness. All projects that have passed the selection and protection stage receive investments for the development of their own production for equity participation in the company (in the amount of $50 thousand in the first and from $500 thousand in the second stages) and joint identification of further development channels, market trends, and free niche. In the production accelerator, entrepreneurs can get "smart money" — the support of the best experts in finance, marketing, strategy, business, and production

	efficiency; individual consultations, and practical assistance in solving problems of any complexity. Participants also become part of an ecosystem that shares knowledge, technology, and useful contacts by bringing together entrepreneurs, manufacturers, and distributors.
THE INTER-CORPORATE IT UNIVERSITY BIONIC UNIVERSITY	BIONIC University (BU) is the first inter-corporate IT university in Ukraine aimed at the training of professionals for the high technology sector, taking into account the actual needs of the IT industry. It is an educational initiative of Vasyl Khmelnytsky's Fund in partnership with leading Ukrainian and international IT companies, including Infopulse, Cisco, BMS Consulting, Ciklum Consulting, MacPaw, Wikimedia Ukraine.
UNIQUE EDUCATION IT-FACTORY UNIT FACTORY unit.ua	UNIT Factory is a platform for educational projects. The IT-factory is being supported by a non-profit public organisation, Osvitoria. The mission of UNIT Factory is promoting innovative development of Ukraine by preparing IT professionals. The platform has two campuses – in Kyiv and in Kharkiv. UNIT Factory in Kyiv is the only private educational institution in Ukraine which operates according to the standards of the French innovative school 42.
SMALL AND MEDIUM ENTREPRENEURSHIP (SME) SCHOOL www.mspschool.com.ua	The School of Small and Medium Entrepreneurship (SME School) is a progressive community of educated representatives of small and medium business, created by Ukrainians for Ukrainians. The purpose of the project is the development of entrepreneurship through the provision of quality relevant knowledge and effective practical skills to entrepreneurs with different levels of experience in all regions of Ukraine.
LEAN INSTITUTE UKRAINE lean.org.ua	Lean Institute Ukraine (LIU) is a project designed to raise the innovativeness and the competitiveness of Ukrainian companies through the implementation of lean methodology. LIU is a member of Lean Global Network. The mission of Lean Institute Ukraine is to support Ukrainian business on the way of transformation by creating a lean community and providing access to international expert knowledge. Lean thinking is about creating the most value for the customer while minimising all kinds of resources, including time, energy, and effort. This approach turns problems into opportunities for development, helps workers to grow, and aids the organisation's leadership in its market.
THE NATIONWIDE OPEN ONLINE PLATFORM ilearn.org.ua	iLearn is a nationwide educational social project of the Osvitoria Social Organization and Kyiv National Economic University's Enactus team, which was created with the support of K.Fund. The purpose of the open online platform is to help talented students from boarding schools, orphanages, and children from poor families to receive academic knowledge to ensure that they successfully pass Standardized External Testing (SET). That, in turn, will let them enter the university and study free of charge. Teachers from Kyiv National Economic University named after Vadym Hetman and Novopecherska School are involved in the preparation of training materials.

Table 8: Regional ecosystem of Ukraine

The science and research ecosystem of the Kyiv region covers the institutes of NASU, which carry out scientific activities in the field of energy and related fields:

1. Institute of Engineering Thermophysics NAS Ukraine
2. Institute of Electrodynamics
3. G. E. Pukhov Institute of Modelling Problem in Power Engineering
4. General Energy Institute
5. THERMAL ENERGY TECHNOLOGY INSTITUTE OF THE NATIONAL ACADEMY OF SCIENCES OF UKRAINE
6. Gas Institute
7. Institute of Renewable Energy of the National Academy the Sciences of Ukraine
8. Institute for Safety Problems of Nuclear Power Plants NAS of Ukraine
9. State Institution "Institute technical problems magnetism of the National academy of sciences of Ukraine"
10. Specialised training department of the National Technical University of Ukraine "Kyiv Polytechnic Institute. Igor Sikorsky" at the National Academy of Sciences of Ukraine
11. State enterprise "State scientific and technical centre for nuclear and radiation safety"
12. Institute for Nuclear Research
13. State Institution "The Institute of Environmental Geochemistry of National Academy of Sciences of Ukraine"
14. Center for Information-analytical and Technical Support of Nuclear Power Facilities Monitoring of the National Academy of Sciences of Ukraine
15. Joint Department of Electrochemical Energy Systems of NAS of Ukraine

The city of Kyiv and Kyiv region have **11 higher education institutions that offer educational programs in electrical engineering**:

1. Kyiv National University of Construction and Architecture
2. Open University of Human Development “Ukraine”
3. State University of Infrastructure and Technologies
4. National Technical University of Ukraine “Igor Sikorsky Kyiv Polytechnic Institute”
5. National University of Food Technologies
6. National Transport University
7. Volodymyr Dahl East Ukrainian National University
8. Kyiv National University of Technologies and Design
9. National Aviation University
10. National University of Life and Environmental Sciences of Ukraine
11. Bila Tserkva National Agrarian University

The authorities on regional development (RDA) at the region level are structural subdivisions of regional state (now oblast military) administrations. Accordingly, they are financed by the heads of military administrations in accordance with the approved monthly plan within the expenditures provided for the relevant regional military administration in the State Budget of Ukraine. The RDA is a non-profit, non-budgetary institution formed based on partnership between the public, private and public sectors, employers' organisations and their associations. The Regional development agency of the Kyiv region supports SMEs to solve issues related to the connection to the electrical networks, provides the registration

of the land plots and the selection of the appropriate premises for business activity. The agency also provides support on:

- Business planning
- Development of a financial model
- Development of a marketing strategy
- Profile studies
- Investment attraction
- Funding
- Business consulting
- Development of the enterprise's export potential

Energy and energy efficiency innovations in Kyiv's region

Automated system "Kyivshchyna is energy efficient"

In the Kyiv region, the Energy Monitoring System "Energy Efficient Kyiv" (hereinafter - CEM) has been implemented and is successfully operating. The specified automated system is installed in order to implement the order of the Cabinet of Ministers of Ukraine No. 732-r dated April 26, 2017 "Plan of measures for the introduction of energy management systems in budget institutions", clause 3 "Regulations on monitoring the consumption of fuel and energy resources by budget institutions".

The main task of the CEM is to ensure daily monitoring of the use of electricity, water and heat resources in budgetary institutions of the population centres of the region by using modern information networks and capabilities for data collection and processing, ensuring control and analysis of energy consumption, forming an energy balance with the aim of implementing measures for energy saving and increasing the effectiveness of the use of budget funds for the payment of energy carriers.

The annual savings for the heating period of 2018 amounted to -5%, 2019 -7% (over 70 million hryvnias) of budget funds for the payment of energy carriers at the expense of energy management - quality management of energy resources at facilities.

Currently, CEM archives and stores data on the consumption of fuel and energy resources of 2,787 objects of the budgetary sphere of the region in 2017-2019. On the 5th of each month, data on energy consumption is submitted to the State Energy Efficiency Agency of Ukraine for the preparation of analytical reports from all regions of Ukraine.

Kyiv's Region Startups in Energy

Solvergy	Ukraine, Kyiv	Solvergy software products allow you to quickly develop energy efficiency projects of systems, buildings and energy sources using Machine Learning and Computer Vision technologies.
OREX	Ukraine, Kyiv	Economical lighting with dynamic (programmed) brightness control: street, industrial, for sports. The company produces ready-made lamps using its own technology under its own trademark.
Smart ION	Ukraine, Kyiv region	Smart modules with built-in scripts to control lighting and electrical appliances, replacing actions normally performed by a person.
Vacuum Gravity Energy	Ukraine, Kyiv	VGE offers a mobile generator that converts temperature differences into electricity and works even underground 24/7.
CLIMATE OF THE FUTURE	Ukraine, Kyiv	A device that helps to eliminate the flow of condensate, save electricity consumption when using climate systems, and also allows you to reduce the risks of overload.
SolarGaps	Ukraine, Kyiv	The TM SolarGaps solar blind system is a 'smart' blind designed with built-in photovoltaic cells that generate electricity that can be used to power devices, store in batteries and/or sell excess electricity to your electricity supplier.
VAR Energy	Ukraine, Kyiv	Support of power grids with the help of distributed energy.
UBESS	Ukraine, Kyiv	Solutions for stabilisation and storage of solar and renewable energy using the most reliable and affordable technologies.
CURRENT	Ukraine, Kyiv	A network of publicly available charging stations for electric vehicles, a project implemented by a private Ukrainian company for the development of electric vehicle transport in Ukraine.
LLC SMART-MAK	Ukraine, Kyiv	Smart meters for any consumption.
ASEM	Ukraine, Kyiv	A complex of software and technical support for remote accounting of fuel and energy resources received from accounting nodes

Table 9: Kyiv's Region Startups in Energy

Regional cooperation with EU

The legal basis for cooperation between Ukraine and the EU in the field of regional development, regional and cross-border cooperation is defined by provisions of the Association Agreement between Ukraine, on the one hand, and the European Union, the European Atomic Energy Community and their Member States, on the other hand (2014), in particular Chapter 27 "Cross-Border and regional cooperation" of Title V "Economic and Sector Cooperation" thereof.
Practical cooperation between Ukraine and the EU in the field of regional development, today, focuses on the following areas:

- enhancing cooperation between local and regional authorities of Ukraine and the EU through the contacts with the European Committee of the Regions (CoR);
- implementation of projects at the regional level funded by the EU financial instruments (European Neighbourhood Instrument) and EU financial institutions (European Investment Bank, European Bank for Reconstruction and Development);
- participation in the implementation of Cross-border cooperation programmes, Eastern Partnership territorial cooperation programmes;
- participation in the implementation of the EU Strategy for the Danube Region and the Danube Transnational Programme;
- cooperationwith the Joint Research Center of the European Commission in the development of regional strategies for smart specialisation;
- involvement of the regions of Ukraine into the activities of European regional associations, namely:

Assembly of European Regions
Council of European Municipalities And Regions
Conference of European Regional Legislative Assemblies
Association of European Border Regions
Conference of Peripheral Maritime Regions of Europe
European Association of Mountain Areas (EUROMONTANA)
Association of European Cities (EUROCITIES)
Covenant of Mayors for Climate and Energy

Ukraine continues to cooperate with the EU in the framework of the **Task Force on Decentralization** established by the EU Committee of the Regions in 2015 with aim to intensify bilateral relations as well as political and technical support to Ukraine's reform of local government and territorial organisation.
Representatives of Ukraine are members of the **Conference of Regional and Local Authorities of the Eastern Partnership (CORLEAP).** Its 9th meeting took place on September 12, 2019 in Turku (Finland). It focused on how cities and regions can contribute to the EU's Eastern Partnership, on building the administrative capacity of local and regional authorities in the EaP and promoting people-to-people contacts across borders.

The Ukrainian side is actively involved in the work of the **EU Strategy for the Danube Region** and the **Danube Transnational Programme**. During 2019-2020 representatives of Ukraine took part in joint meetings of Priority Area Coordinators and National Coordinators of the Danube Strategy, in the annual Forums of the Danube Strategy, as well as in High-level meetings on the implementation of the EU macro-regional strategies.
Ukraine supports the initiative to create a **new EU macro-regional strategy for the Carpathian region**, which aims to promote the development of the Carpathian macro-region, taking into account its unique natural and cultural heritage and internal development potential. In September 2018, Poland, Slovakia, Ukraine and Hungary signed a Declaration of Intent to establish a new EU macro-regional strategy for the Carpathian region. In October 2018 the comprehensive proposal on the initiative was submitted to the European Commission. In February 2020, the Carpathian Executive Council was established at the level of representatives of the governments of the Carpathian region to promote the initiative.

Ukraine also participates in four **Cross-border cooperation programmes of the European Neighborhood Instrument** 2014-2020 (ENI CBC programmes) in accordance with the agreements concluded between the Government of Ukraine and the EC in December 2016, in particular: "Poland - Ukraine - Belarus", "Black Sea Basin", "Ukraine - Romania "and" Hungary - Slovakia - Romania - Ukraine ". Ukrainian project partners jointly implemented more than 350 projects in cooperation with 11 partner countries.

On January 28-29, 2020 (Brussels), the Ukrainian delegation took part in the first annual Conference of CBC Programmes within the framework of European Territorial Cooperation for 2021-2027 (Interreg NEXT). In the new programming period, Ukraine intends to continue its participation in the four mentioned CBC programmes.

The Joint Document presented by the European Commission on the formation of future CBC programmes notes the strategic importance of closer cooperation between EU member-states and Ukraine within the following **priority areas:** *environment* (in particular, access to clean drinking water), *sustainable transport*, *energy education*, *health and culture*, *economic and tourism* cooperation, and *resolving of cross-border problems* in various sectors.

In 2021-2027, Interreg NEXT CBC programmes at the EU's external borders with partners from neighbouring countries will receive funding from two sources - the Neighbourhood and International Cooperation Instrument (NDICI) and the European Regional Development Fund (ERDF). The specific budgets of the new programmes are expected to be determined after the EU Multiannual financial framework for 2021-2027 is adopted.

The **European Innovation Ecosystems** as a part of Horizon Europe Pillar III "Innovation Europe" focuses on building interconnected, inclusive, and efficient innovation ecosystems that support the scaling up of companies and drive innovation.

The EU has developed the New European Innovation Agenda, which helps deep- tech developers implement projects and commercialise them by gaining access to funding, innovation ecosystem services, and opportunities for knowledge and skills development. As part of the agenda, the **Regional**

Innovation Valley initiative was launched to unite the interests of regional authorities, innovative businesses and their stakeholders along the entire added value chain, both regionally and internationally.

4.3.2 Energy Ecosystems

Energy independence of Ukraine is one of the key factors in the development of innovative ecosystems related to energy, as well as the main vector of the implementation of innovations in the sector.

The Ukrainian energy system is already part of the European system, and its further integration is underway. EU standards and market mechanisms are being introduced to ensure transparency and create investment opportunities. The physical possibilities for exporting and importing electricity to the countries of the European Union are increasing.

Measures are being taken to increase gas production, which should be sufficient to meet Ukraine's internal needs. Ukraine is actively attracting private investors, including the largest global companies. The country has the ambitious goal of becoming the gas hub of Europe, as Ukraine has the largest gas storage facilities on the continent.

Today, energy recovery means repairing, rebuilding, constructing, reconstructing and creating reliable protection of power generation and distribution facilities. It also means energy efficiency and economical energy consumption.

The ultimate goal of the changes is energy independence and energy security for the state. The ability to be self-sufficient and export energy resources, to join the whole of Europe in a green energy transition and to guarantee a safe environment for future generations.

1. **Restoration of power generation and distribution systems**

Following the Russian attacks on Ukraine's energy system, the state has launched a large-scale campaign to repair, rebuild and reconstruct Ukraine's energy system. In addition, reliable active and passive protection of power generation and distribution facilities is being created.

2. **Further integration of the energy systems of Ukraine and Europe**

Ukraine implements European regulatory documents and market rules in accordance with European standards. In March 2022, Ukraine received the so-called “visa-free" regime with the EU in the energy sector. We joined the ENTSO-E, first temporarily and then permanently from 28 November 2023.

The government will also continue extensive work to increase the physical capacity for the export and import of electricity with the countries of the European Union. As part of the implementation of the Roadmap for the integration of the electricity markets of Ukraine and the EU, we will continue work on the introduction of long-term auctions on the electricity market within the framework of the European JAO platform, the implementation of the necessary steps to unify the markets (market coupling) and joining the EU balancing platforms. In addition, the government is working on the implementation of the fourth EU energy package.

3. Extraction and storage of natural gas

The government's strategic goal is to meet Ukraine's demand for its own natural gas. To this end, the government will continue to actively develop public-private partnerships, implement the mechanism of joint production agreements and launch new gas production projects. We have also certified our underground gas storage facilities, and today, despite the war, European traders are storing the largest volume of gas ever in Ukrainian gas storage facilities. Ukraine has the ambitious goal of becoming the "gas safe" of Europe, because we have the largest gas storage facilities on the continent.

4. Development of small-scale generation, decentralisation of the energy system, "Green Deal"

In order to be less vulnerable to hostile attacks on the energy system, the state will promote the development of small-scale power generation and continue to implement the energy system decentralisation programme. Ukraine will continue to implement the provisions of the European Green Deal.

Energy innovation ecosystem actors include:

- Cabinet of Ministries of Ukraine
- Ministries (Ministry of Energy of Ukraine, Ministry of Education and Science of Ukraine (MESU), Ministry for Communities, Territories and Infrastructure Development of Ukraine (Ministry of Infrastructure, Ministry of Environmental Protection and Natural Resources, Ministry of Economy of Ukraine, Ministry of Digital Transformation of Ukraine)
- the State Agency on Energy Efficiency and Energy Saving of Ukraine (SAEE)
- HEIs, providing energy-related education programs
- NASU and its research institutes of the NASU
- Learning Energy Efficiency Networks
- SMEs and startups
- Energy sector facilitators
- NGOs, Think Tanks
- Funds and programs (GIZ, Ukrainian Startup Fund, National Research Foundation of Ukraine (NRFU), Ukrainian Fund of Energy Efficiency and Energy Saving, the State Fund for Decarbonization and Energy-Efficient Transformation)

The Cabinet of Ministers of Ukraine approved the National Action Plan on Energy Efficiency until 2030, which aims to achieve the national goal of energy efficiency which states that primary and final energy consumption in Ukraine in 2030 should not exceed respectively 91 468 thousand and 50 446 thousand tons of oil equivalent.

Both of the mentioned ministries, the Union of Rectors and the individual HEIs have signed a number of MoUs to ensure cooperation in the energy-related education, knowledge exchange and innovation support for the development of educational, scientific and technical potential of the country in energy efficiency and energy modernisation.

The Renewable Energy Institute as part of the National Academy of Sciences of Ukraine conducts research studies in the following fields: physical and technical processes of transformation and use of

solar energy; scientific bases of transformation and use of wind energy; thermophysical bases of geothermal energy use; processes of transformation and use of energy of rivers and seas; transformation and use of renewable organic energy sources; technologies and systems of integrated use of renewable energy sources.

As a result of research, the natural potential has been studied and an atlas of renewable energy resources in the regions of Ukraine has been developed. More than 20 state standards regulating renewable energy and its role in energy efficiency have been developed.

A series of lectures has been developed and the Scientific and Educational Union "Joint Renewable Energy Department" is established at the National Technical University "Igor Sikorsky Kyiv Polytechnic Institute". There are specialised scientific councils for thesis (PhD) defense on energy saving and renewable energy.

An inter-branch centre for renewable and hydrogen energy technologies transfer has been established. It also acts as an educational and exhibition centre.

Perspective scientific research is carried out on the following issues: trends in renewable and hydrogen energy development in Ukraine and prospects for international cooperation; creation of new equipment and technologies of RES; integration into the power system of Ukraine; increase of reliability of power systems by complex use of renewable sources, systems of accumulation of electric and thermal energy, development of methods of energy efficiency increasing of RES.

Besides, from 2017 to 2021, several studies to implement energy efficiency incentive structures in Ukrainian industrial companies were conducted within the framework of the project "Advisory Services for Energy Efficiency in Companies" implemented by GIZ on behalf of the German Government in cooperation with the Ministry of Economy and the State Agency on Energy Efficiency and Energy Saving of Ukraine. In particular, industrial enterprises received energy audits following ISO 50002. The results of 63 of them proved the effectiveness of energy audits as a policy to promote energy efficiency in industrial enterprises. A theoretical and practical guide to conduct such an audit at other companies was developed[65]. Another study was conducted to understand the feasibility of establishing the Learning Energy Efficiency Networks (LEEN) in Ukraine. As a result, 3 LEENs were piloted. They are "Network of energy-efficient enterprises of Lviv region", "Networks of energy-efficient bakers", and "Networks of manufacturers of building materials". 34 member companies have agreed on their joint voluntary commitment target - within two years to reduce their energy consumption by 10, 500 MWh, equivalent to 6, 270 tons of CO2- eq. As of 2021, It was over fulfilled as 20 375 MWh were saved (equivalent to 8 002 tons of CO2-eq). It is more than UAH 38.4 mln. In addition to the effectiveness of LEEN, the study demonstrates the willingness of industrial enterprises to implement mechanisms such as voluntary agreements.

The Ministry of Education and Science of Ukraine supports innovations in the energy sector through competitive funding of the projects in the development of new technologies of energy transportation, introduction of energy-efficient, resource-saving technologies, development of alternative energy

[65] https://saee.gov.ua/sites/default/files/Guidebook_03112020.pdf

sources (among others). The NASU also supports energy-related scientific and technical projects through annual competitions.

In Ukraine, 68 higher education institutions provide training in electrical engineering that includes the following areas:

electrical power engineering, electrotechnics

energy machine building

nuclear power engineering

thermal power engineering

renewable energy sources and hydropower

The regional distribution of higher education institutions offering training in electrical engineering is presented in the table below.

Region		Region	
Kyiv region	11	**Kirovograd region**	2
Dnipropetrovsk region	9	**Mykolaiv region**	2
Kharkiv region	8	**Sumy region**	2
Odesa region	4	**Chernihiv region**	2
Ternopil region	4	**Ivano-Frankivsk region**	1
Zhytomyr region	3	**Rivne region**	1
Zaporizhzhya region	3	**Kherson region**	1
Lviv region	3	**Cherkasy region**	1
Poltava region	3	**Chernivtsi region**	1
Khmelnytsky region	3	**Donetsk region**	0
Vinnytsia region	2	**Zakarpattya region**	0
Volyn region	2	**Autonomous Republic of Crimea**	0

Table 10: Regional distribution of higher education institutions with training in electrical engineering

Thus, three key regional centers of university training in electrical engineering have been formed in Ukraine: Kyiv, Dnipro and Kharkiv regions.

Scientists are engaged in the development of scientific potential in the field of energy and energy efficiency on the basis of the following scientific institutions of the NASU:

- Institute of Technical Thermophysics of the National Academy of Sciences of Ukraine;

- Institute of Electrodynamics of the National Academy of Sciences of Ukraine;

- G.E. Pukhov Institute for Modelling in Energy Engineering;

- Department of Hybrid Modelling and Control Systems in Energy Engineering, G.E. Pukhov Institute for Modelling in Energy Engineering;
- Institute of General Energy of the National Academy of Sciences of Ukraine;
- Thermal Energy Technology Institute of the National Academy of Sciences of Ukraine;
- Renewable Energy Institute of the National Academy of Sciences of Ukraine;
- State Institution "Institute of Technical Problems of Magnetism of the National Academy of Sciences of Ukraine".

The institutes under the National Academy of Sciences of Ukraine actively cooperate with industry, which contributes to updating the topics of applied and fundamental research, to link them to specific practical needs. The cooperation with the design bureaus "Pivdenne" named after M.K. Yangel", "Progres" named after O.G. Ivchenko, "Luch", "Arsenal" is ongoing.

The list of new partners includes domestic industrial giants like the state enterprise "Antonov", joint-stock company "Turboatom", joint-stock company "Motor Sich", research and production complex "Zorya" - "Mashproekt", metallurgical plant "Azovstal", research and production Pavlograd Chemical Plant, "Ukroboronprom" State Concern, state enterprise "Energoatom" and many others.

During 2020, the institutions of the National Academy of Sciences of Ukraine executed 118, including more than 70 new, contracts for the export of scientific products totalling about UAH 120 mln (approximately 4.5 mln EUR). During 2021 - 173 contracts for UAH 138.4 mln (approximately 4.2 mln EUR) were executed.

The geography of foreign economic cooperation of the institutions of the National Academy of Sciences of Ukraine covers about 30 highly developed countries. The most successful cooperation of the NASU's institutions with corporations, companies, enterprises of China (23 contracts), Lithuania (13 contracts), the USA (12 contracts), France (11 contracts), Sweden (8 contracts), Italy (6 contracts), Germany (5 contracts), Great Britain (3 contracts). The foreign economic activity of the institutions of the National Academy of Sciences of Ukraine covered a wide range of scientific areas. Among them - the development of principles and methods of optical registration of information, the creation of information systems, information processing systems and sound reproduction from rare media; creation of radio engineering means and systems for studying the environment with the help of radio astronomical and radio physical methods; creation of radio physical devices and devices; development, manufacture and supply of devices for electron beam welding; development and creation of new thermoelectric devices and devices based on them; development, manufacture and sale of scintillation crystals and products from them; provision of services in the field of blast furnace iron production; research in the field of nuclear science and technology, radiation materials science; fine organic synthesis of new classes of organic and elemental compounds, etc.

For example, specialists of the Institute of Information Registration Problems of the National Academy of Sciences of Ukraine for Huawei Technologies Co. Ltd (PRC) has developed and modelled a laser beam homogenizer, on the basis of which a corresponding optical scheme of a laser projector has been proposed.

Under contracts at the E.O. Paton Institute of Electric Welding were developed, manufactured and supplied to Sviten Co. Ltd (UK) six sets of electron beam welding machines; conducted a set of R&D on the development, manufacture and commissioning of an installation for electrodynamic processing of welded joints for China Great Wall Industry Corp. (PRC). For Farwell Company Limited (Hong Kong) were developed, manufactured and installed a set of equipment for non- destructive quality control and deformation of welded materials by broadband and digital image correlation.

Under the agreement between the Radio Astronomical Institute and RST Remote Sensing Technologies Inc. (Turkey) was developed, manufactured and delivered an X-band land / sea survey radar station.

Specialists of the Institute of Single Crystals developed and supplied products made of artificial single crystal sapphire (complex finely ground elements, polished optical elements windows), optical blanks and optical elements made of artificial single-crystal sapphire with a colouring impurity, polished optical blanks made of artificial single-crystal YAG for Impex High Tech GmbH (Germany), Fisher & Paykel Healthcare Limited (New Zealand), Optogama UAB (Lithuania).

Under a contract with Westinghouse Electric (Sweden) scientists from the Kharkiv Research Institute of Physics and Technology provided scientific and technical support for the design of reactors in which Westinghouse nuclear fuel is operated. Neutrophysical, thermohydraulic, mechanical calculations of nuclear fuel loads were performed in order to confirm its safe operation.

Ukraine is already implementing several initiatives to establish a link between business and science: **The Open Innovation Platform**, developed as part of a number of international projects by the Ukrainian Institute of Scientific and Technical Expertise and Information (UKRISTEI), acting as an aggregator of existing scientific developments; the **Science2Business Platform** of the Ministry of Education and Science of Ukraine; and the Nazovni.Tech Platform of the Ministry of Foreign Affairs of Ukraine.

Digital tools:

- The Science and Business Platform is an online platform for communication and effective interaction between business and the scientific community, enabling businesses to find scientific results, scientific research and scientists – to realise their capacity and commercialise the research results.
- Ukrainian Tech Ecosystem Overview is an online platform for business information about IT-companies, people, investors and the whole tech ecosystem of Ukraine in general.

Ukraine's startups ecosystem

Ukraine's startups ecosystem grew rapidly in 2019–2021; a significantly higher number of organisations entered the market (57 out of 83 surveyed) than in 2011–2018. This positive trend was disrupted by Russia's full-scale invasion of Ukraine. In 2022, only five companies were established, four of which were founded just before the war began[66]. However, the evaluation of startup activity during the war varies. The results of a survey of investment funds in 2023 show that startups are highly resilient in turbulent times.

[66]https://tech.eu/2023/06/11/beyond-military-tech-emerging-trends-in-ukraines-early-stage-startup-scene-for-investors-to-look-after/

In order to support startups and better protect investments and intellectual property in Ukraine, a pilot project for startups related to IT, cybersecurity, artificial intelligence, and now defence has been launched—DIIA City. Residency in DIIA City provides significant tax benefits for both the company and its employees.

In 2021, the Ministry of Education and Science of Ukraine in partnership with the Ukrainian Startup Fund introduced a quarterly event – Science & Business StartupBootcamp and Science & Business Demo Day to combine scientific and innovative potential of scientists, start-ups, companies, experts, investors, media and to find innovative solutions, raise awareness on business, marketing, sales, investment and innovation.

The Ukrainian Startup Fund was established in 2018 as a state-owned legal entity founded by the Cabinet of Ministers of Ukraine that focuses on supporting Ukrainian start-ups by offering non-refundable and non-equity grants for all programmes from $ 10 000 up to $ 50 000 per start-up. It was set up to boost the development of the Ukrainian start-up ecosystem. The activity of the Fund is supported by donors and international programs among which are the following: European Innovation Council, USAID, World Bank Group, WNISEF, GIZ, CRDF Global.

The activities of the Ukrainian Startup Fund are aimed at:

- competitive selection of innovative projects on a permanent basis;
- providing startups with funding in the form of two types of grants: for pre-seed and seed projects;
- constant support, communication and assistance in promoting start-ups, their further entry into global markets;
- opportunity for the start-up to undergo an acceleration programme for grant funds in one of the leading international and Ukrainian Accelerators accredited by the Fund, of their choice – up to $ 10000 per start-up;
- global promotion through USF Innovation Vouchers Programme (Web Summit 2021 in Lisbon, CES 2022 in Las Vegas, etc.) – up to $10 000 per start-up;
- constant feedback and valuable advice from qualified experts of the Fund with significant experience in the field of innovation and investment activities;
- implementing corporate innovation programme (start-up scouting for Ukrainian corporations, such as DTEK, MHP, Glovo, Plug and Play, OKKO, ArcelorMittal, Vodafone, etc.);
- expanding and establishing partnerships and cooperation with representatives of the national and international start-up ecosystem.

Ukrainian Startup Fund regularly holds events with the most important stakeholders in the ecosystem to strengthen the skills, networking and communication of start-ups. More than 300+ events (Bootcamps, Hackathons, Workshops, Crash tests, etc.) were conducted by USF in cooperation with different government agencies and the leaders of the innovation ecosystem (CRDF, USAID, GIST, GIZ, etc.). Since its inception, the fund has supported more than 330 start-ups during 36 global tech events around the world.

The Ministry of Education and Science has launched the All-Ukrainian Innovation Festival to promote the developments of scientists and innovators, as well as to attract investors to finance the implementation of new developments. The All-Ukrainian Innovation Festival is a platform where scientists, innovators and start-ups can show their best projects, compete for their financial support and meet potential investors. As part of a series of events, Ukrainian innovators presented their latest developments in IT, education, healthcare, agriculture, energy efficiency, ecology, assistance to people with special needs and medicine spheres.

At the National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnic Institute" the Festival of Innovative Projects, the Sikorsky Challenge is held. The festival has been held annually since 2012 and has become very popular among students and entrepreneurs. Within the framework of the Festival there is a competition of start-ups and thematic forums dedicated to the development of innovative economy at the regional, national and international level.

UA Startup Landscape in Energy

The majority of energy startups have entered the international market and are currently affiliated with the EU and US ecosystems

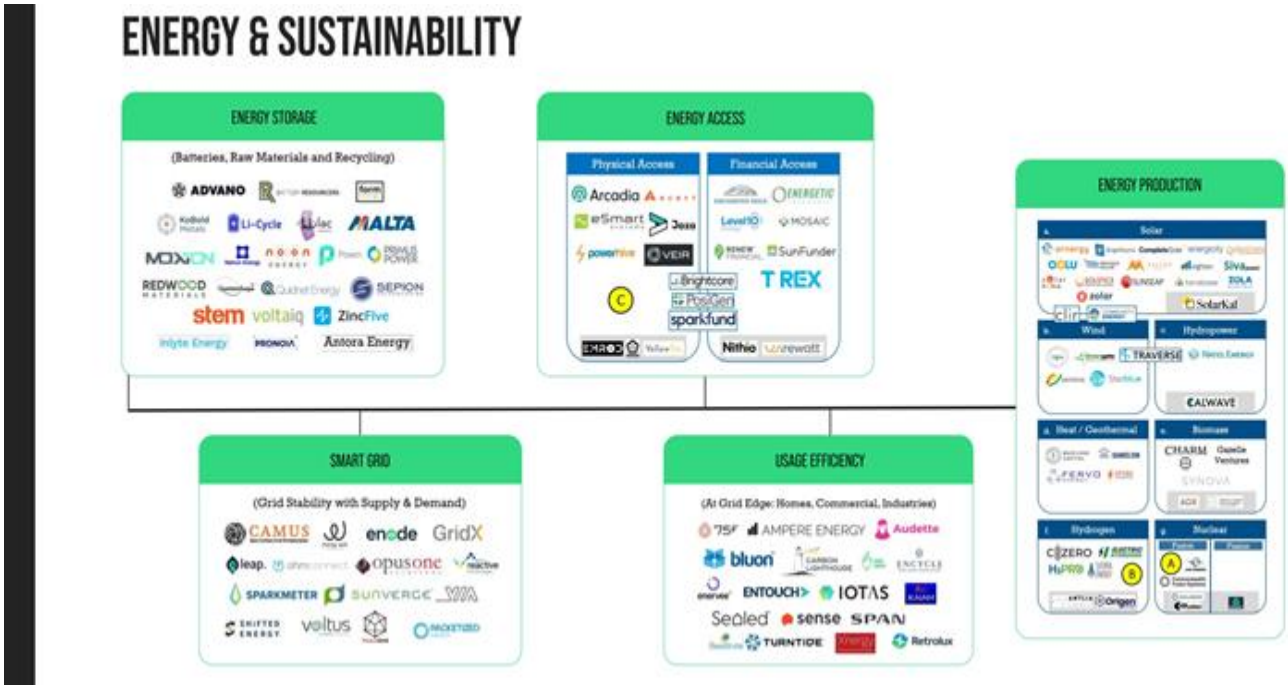

Figure 11: Ukrainian Startup Landscape in Energy

A network of **business incubators and business accelerators** is functioning in Ukraine to support start-ups. Among the most active are the following: GreenCubator, Sikorsky Challenge Innovation Holding, eō Business Incubators, Innovation Startup Entrepreneurship (ISE) accelerator 1991 Accelerator, Challenger Accelerato, iHUB powered by NUMA, IoT Hub Laboratory-Accelerator, VACUUM DEEP TECH ACCELERATOR, YEP Accelerator.

4.3.3 Programme/Project based Ecosystems

As of now, there are no mature project or program-based innovations in energy ecosystems in Ukraine. However, there are several projects and programs in which entities from Ukraine take part and those actors have perspectives to develop innovation ecosystems.

Currently, Ukraine is an associate participant in several EU grant programs such as "Horizon Europe" and Research and Training Program of the European Atomic Energy Community (Euratom), “Digital Europe”, “COST”, "Creative Europe", "EU Civil Protection Mechanism", "Connecting Europe Mechanism " (CEF), EU Anti-Fraud Program, EU Justice Program, "Citizens, Equality, Rights and Values" (CERV), iNTERREG, Erasmus+.

These finance a variety of fields, including health, climate, taxation, customs, digital transformation, to name but a few. Ukrainians can present their project ideas for various funding programmes, and they will receive support in all stages of implementation.

Over the past year, Ukraine has joined the following EU funding programmes: LIFE, Copernicus, EU4Health, Fiscalis, Digital Europe, Single Market, and Customs. These are explored in more detail below.

LIFE and Copernicus programmes

Ukraine joined the LIFE Programme for climate and environment in June 2022. This programme is an EU financial instrument for environmental and climate protection. Since its establishment, the programme has co-financed more than 5,600 environmental protection projects in and outside the EU.

It is an opportunity to preserve biodiversity, restore ecosystems, and prevent water and soil pollution. The budget of the programme for the 2021-2027 period is about €5.4 billion (which is 0.48% of the total EU budget). Ukraine can submit projects and receive funds to restore the environment from the damages of the war. Ukraine’s participation in the LIFE programme is an opportunity to implement environmental projects. It also provides means to learn and implement developed European procedures in the field of environmental protection.

In the short term, the LIFE programme will be able to support Ukraine’s recovery efforts through needs analysis, mobilisation and capacity development of various factors to clean up soils and water bodies with the help of ecological solutions. In the medium and long term, as in other LIFE countries, projects can be aimed at developing and demonstrating eco-innovative methods and approaches, promoting the best practices and behavioural changes to help restore and preserve the environment, etc..

Based on the Copernicus programme satellite data, Ukraine will have access to up-to-date statistics on environmental monitoring and the effect the war has had on the environment. The data will include forest fires, illegal logging, soil contamination, air quality, marine ecology, and radiation monitoring.

EU4Health programme

In July 2022, the European Commission signed an agreement associating Ukraine with the EU4Health programme. It will enable our health system to respond to immediate needs and contribute to long-term recovery. State authorities, non-governmental organisations and small and medium-sized businesses will be able to receive funding for health care improvement projects on equal terms with EU member states, Norway and Iceland. It is the largest programme in the field of healthcare, with €5 billion allocated for the seven-year duration of the programme (2021-2027).

- Ukraine will be able to receive funding to support the health sector and respond to urgent needs.
- EU4Health will help to mitigate the damage associated with hostilities, as well as finance Ukrainian public and private projects that will play a part in further reconstruction.
- Ukraine's accession to EU4Health will make it possible to better prepare Ukraine's healthcare system for European standards and facilitate Ukraine's sectoral integration with the European Union.

Digital Europe programme

Ukraine joined Digital Europe in September 2022. This programme provides funding for the digitalisation of European countries. The goal is to accelerate economic recovery and digital transformation. Ukraine will have access to 4 out of 5 capacity areas with a total budget of about €6 billion from 2021 until 2027:

- High-performance computing
- Artificial intelligence, data, and cloud services
- Digital skills
- The use of digital technologies in the economy and society

It is worth mentioning that in the middle of July 2024 Ukraine as the associated participant of the Digital Europe programme joined the Network of European Digital Innovation Hubs[67]. Among the 12 winner-consortiums (EDIHs) within the Network of European Digital Innovation Hubs call there are KAU and USF (WEnnovate partners). Hence, KAU received the Seal of Excellence award that gives the relevant consortium (coordinator - Ukrainian Cluster Alliance) to become the EDIH and USF as part of the WIN2 EDIH consortium (coordinator - Kyiv National Economic University named after Vadym Hetman) received the status of EDIH.

Joining the European Digital Innovation Hubs (EDIHs) network will significantly benefit Ukraine's innovation ecosystem, especially in the energy sector. Except the grant funding in amount of up to 4.5 mln EUR dedicated to Ukraine, the Ukrainian innovation ecosystem will gain access to expertise and knowledge, testing and experimentation, cross-border partnerships and technology transfer, funding and investment opportunities, as well as enhanced support for SMEs and start-ups.

In summary, joining the EDIH network can significantly boost Ukraine's innovation ecosystem by providing access to resources, expertise and networks, as well as facilitating the adoption of digital technologies and the development of new business models.

[67]https://thedigital.gov.ua/news/ukrainski-obednannya-uviyshli-do-merezhi-evropeyskikh-tsifrovikh-innovatsiynikh-khabiv

Participation in the programme brings Ukraine closer to the EU's Single Digital Market. This is an opportunity to adopt the ways of EU countries and share our own, as well as strengthening joint digital capabilities and more effectively countering russian aggression. The programme will contribute to the development of Ukrainian companies, researchers, and state authorities with the EU, through the construction of joint digital infrastructures. It will also contribute to further digital transformation.

Single Market programme

Facilitating access to EU markets, promoting entrepreneurship, learning from EU business experience, and modernising industry – these and other opportunities will be available to Ukrainian businesses under the EU's Single Market Programme, which Ukraine joined in February 2023.

Applicants from Ukraine are eligible to participate in the following components of the Programme:

- strengthening the competitiveness and sustainability of small and medium-sized enterprises (about €1 billion funds allocated),
- the production and dissemination of high-quality European statistics (about €546 million available).

Ukraine's accession to this programme will strengthen cooperation with the EU, which is especially important in view of the European integration process and Ukraine's EU candidate status. Participation in the programme will provide additional support for Ukrainian entrepreneurs and help strengthen the Ukrainian economy.

Fiscalis programme

Ukraine has joined the Fiscalis programme for cooperation in the field of taxation in September 2022. Protection of financial and economic interests of the EU and its member states against tax fraud and tax evasion, as well as the improvement of tax collection and administration are just some of the objectives of this programme with a €269 million budget for 2021-2027.

Participation in Fiscalis will improve partnership relations between tax administrations of Ukraine and EU member countries. This will be a catalyst for mutual exchange of experience and best practices, which in turn will strengthen the institutional capacity of fiscal bodies. Ukraine will have the opportunity to use modern European IT systems in the field of taxation. Cooperation within Fiscalis will allow the creation of powerful European-style tax authorities. Moreover, joining the programme will also better equip Ukraine to become a member of the EU.

Customs programme

The Customs programme (joined by Ukraine in September 2023) supports the development and operation of central IT systems for customs in the Union, and the essential cooperation between customs authorities across the EU.

Participating in the programme will help Ukrainian customs administrations handle increasing trade flows, emerging trends and technologies with more efficiency, while also being better equipped to respond to security threats.

Connecting Europe Facility

On 6 June 2023, the European Commission signed an agreement associating Ukraine with the Connecting Europe Facility (CEF) programme for infrastructure funding. This programme contributes to the European Green Deal objectives and the Digital Decade 2030 targets to promote greener and more sustainable trans-European transport and energy networks as well as digitalisation.

This Programme will enable Ukrainian project promoters to apply for EU funding for projects of common interest in the transport, energy and digital realms, further improving Ukraine's connectivity with its EU neighbours. It will support Ukraine's integration within the EU Single Market, promote growth, jobs and competitiveness. In 2023 Ukrainian project developers became eligible for CEF Energy and CEF Digital funding for Projects of Common Interest (PCIs) for the EU and third countries.

The **EU COST (The European Cooperation in Science and Technology)** programme promotes cooperation between researchers and innovators from different countries, providing opportunities for establishing links between researchers and innovators to strengthen Europe's capacity to address scientific, technological, and society challenges.

The **Enterprise Europe Network (EEN)** has a significant impact on the development of network effects in business and science cooperation. With the help of the EEN, in addition to finding business partners and customers, Ukrainian SMEs have the opportunity to promote their innovations and technologies in the EU markets, as well as to seek investors and partners.

These many programmes come on top of other flagship EU initiatives, in which Ukraine has actively participated for many years, including:

- **Horizon Europe** (a key funding programme for research and innovation).
- **Creative Europe** (a programme to support the culture and audio-visual sectors).
- **Erasmus+** (a programme to support education, training, youth and sport in Europe).

Horizon Europe Pillar III, which includes the European **Innovation Council (EIC), European Innovation European Institute of Innovation and Technology (EIT)** in various industry areas under the EIT Food, EIT Energy, EIT Digital, EIT Manufacturing, EIT Health partnerships, and more. An important step to support innovation in the process of Ukraine's recovery could be the introduction of a similar programme to finance the full "from-idea-to-market" chain of innovation creation, similar to the EIC programme. The European Institute of Innovation and Technology competitions support projects that help innovative SMEs increase their research and innovation capacity and performance, and successfully engage in global value chains and new markets. in Ukraine, the European Institute Institute of Innovation and Technology (EIT) is represented by the **EIT Community RIS Hub Ukraine.**

Specific support for Ukrainian research and innovation

In view of Russia's ongoing war of aggression, Ukraine faces increasingly damaged research infrastructure, logistical and financial difficulties in maintaining research activities in the country, as well as a dangerous brain drain.

From the first day of Russia's unjustified and illegal war against Ukraine, the European Union and its allies have made the collective decision to support Ukraine.

The European Commission is not engaging into further cooperation projects with Russian entities and suspending the preparations of grant agreement for the projects under Horizon Europe programme that involve Russian research organisations as well. The EC also suspends any payment to Russian entities under existing contracts.

The EC strongly committed to ensuring a continued successful participation of Ukraine and Ukrainian entities in Horizon Europe and Euratom Research and Training programmes.

Consequently Ukrainian scientists and researchers are considered as key participants in the EU Framework programmes for R&I.

On 9 June 2022, the Agreement associating **Ukraine to Horizon Europe, the EU research and innovation programme (2021-2027), and to the Euratom Research and Training Programme (2021-2025)** entered into force. The Ukrainian research and innovation actors can fully participate in these programmes on equal terms with entities from the EU Member States.

Ukraine does not have to contribute financially for the present and there is a general encouragement across the Horizon Europe Work Programme to create opportunities, where possible, for the affected persons and entities of Ukraine.

In addition, the EU offered dedicated tangible support to the Ukrainian research and innovation community.

Dedicated initiatives:

- ***MSCA4Ukraine*** (€25 million) offered fellowships to displaced researchers of Ukraine in the EU and Associated Countries.
- ***Horizon4Ukraine*** has over 475 grants projects as opportunities for researchers or other specialists from Ukraine to become involved in ongoing EU-funded research & innovation projects
- ***Research Infrastructure (RI)*** service providers in health, green, digital and frontier knowledge are encouraged to offer fast-track access to Ukrainian researchers
- ***EU Mission for Climate Neutral and Smart Cities***: €5 million action will support peer-to-peer cooperation with the Ukrainian cities to help them integrate climate neutrality in local recovery plans
- ***Human Frontier Science Program*** for health scientists from Ukraine
- ***Call on Political perspectives for the Eastern Neighbourhood and Western Balkan***s required the participation of at least one entity from Ukraine, Georgia or Moldova
- ***Excellence Hubs Initiative***: Ukrainian entities encouraged to apply for 'mentoring scheme' on innovation
- ***Tech4Ukraine*** - a platform to mobilise European actors around efforts to help maintain and develop digital infrastructures, capacities and skills for and with the Ukrainian people.

Calls to support cooperation frameworks

Strategic Partnership on Raw Materials

- Earth Observation platform, products and services for raw materials
- Technologies for extraction and processing of critical raw materials (IA) (still opened)

- Administrative cooperation arrangement on Copernic data access and Earth Observation data exchange
- Designing space-based downstream applications with international partners

Other available support

- ***EIC4Ukraine*** (€20 million) offers financial support and advice to deep tech start-ups within the **Seeds of Bravery** project that is implemented by the USF as part of the UASEEDS consortium[68]

Based on a detailed analysis of the situation of UA Innovation Ecosystem after Russian invasion, partners (6 Ukrainian partners and 16 partners from 12 other EU member States with an extensive outreach capacity spanning across key EU and global markets) have put together a proposal aimed at providing support to counteract the harm done to Ukrainian startups and deep tech SMEs in the short term, building a framework that supports the Ukrainian Government's goal of becoming a 'start-up nation', and increasing the role of innovators and the deep tech industry in driving growth. This will be achieved through a comprehensive portfolio of support services that combine cascade funding (10k-25k-50k grants), access to finance actions (connecting to public funds and private investors, training on EIC, EIT and other cascading opportunities etc.), deep-tech-focused incubation and acceleration programmes, and market access initiatives (targeting 10+ countries, soft landing in 10 key sectors/verticals, and working spaces in 50+ locations across Europe). Pan-European integration – which brings UA innovation closer to investors, accelerators, potential buyers, innovation agencies and peers - will also be a key component of this project.

As of July 2024, the first 59 Ukrainian startups have been awarded € 2 million in grant funding from the Seeds of Bravery, three of them are related to the energy sector:

- **Briller.House** creates a network of production hubs for fast delivery of beautiful, modern, comfortable and carbon-negative buildings.
- **Metaenga** — XR Training Platform is designed for industrial enterprises and educational institutions to empower global workforce development and workplace safety in energy sectors.
- **OptySun** is a sustainable, technologically advanced, portable water purification system, utilising solar powered, high efficiency filtration to provide clean drinking water.

- ***Hop On Facility*** allows for Ukrainian legal entities to join ongoing Horizon projects that have no partner from the Widening countries.
- ***Joint fellowship initiative with the European University Institute (EUI)*** in science for policy competences and JRC's calls to access its 60 unique research infrastructure facilities, including nuclear, are open to Ukraine. ***JRC*** provides policy advice on smart specialisation and technology transfer and carries assessment work of demographic future of Ukraine and the post-war water-related needs.
- ***Support to Eastern Partnership (EaP) partner countries*** – provides resources to help increase participation in Horizon Europe.

[68] https://seedsofbravery.eu/

Special attention deserves the activity of the **funds that finance energy solutions** to support Ukrainian businesses and civilians to overcome the unprecedented energy damages and losses due to the Russian war in Ukraine, for instance:

- ***The Energy Support Fund of Ukraine***[69]. It was created in April 2022 at the initiative of the Minister of Energy of Ukraine Herman Galushchenko and the European Commissioner for Energy Kadri Simson. This is a unique mechanism for consolidating aid from partners who want to support Ukrainian energy companies in ensuring a stable energy supply during the military aggression of the Russian Federation. The most urgent needs of Ukrainian energy companies were financed from these funds, including the purchase of generators, power transformers, switches, spare parts, technical equipment, materials, special equipment, fuel, and means of physical protection of energy facilities. Most of the funds were allocated to meet the urgent needs of energy companies from the front-line regions - Kharkiv, Mykolaiv, Sumy, Zaporizhzhia, Kherson, Odesa.
- ***The Energy efficiency fund***[70]. The EEFund's mission is to raise Ukraine to the European level of energy efficiency by reducing the level of energy consumption and CO2 emissions in the residential sector. The Energy Efficiency Fund provides support to homeowners' associations (HOAs) to implement energy-efficient measures by providing grants and implementing complex technical solutions taking into account the best European practices for thermal modernization of buildings. The EEFund's activities are financed by the State Budget of Ukraine, financial support from the EU and the German government.

Among the funding competitions being run with international partners, particularly the UK, to support and develop energy innovations that will help Ukraine's recovery and reconstruction, **Innovate Ukraine**[71] is worth mentioning, which will provide up to £10 million to help companies develop highly innovative, sustainable energy technologies and business models that can specifically support the recovery of Ukraine's energy system.

Information in numbers on Ukraine's participation in Horizon Europe

Horizon Europe Office in Ukraine (HEOinUA) highlights general statistics on the participation of Ukrainian organisations in joint projects under Horizon Europe (as of July 01, 2024).

✓ **1406 applications** were submitted, which is 0.38% of all applications under the HE.

✓ **159 grant agreements** were signed (1.37% of all signed) for 46.41 million EUR (0.11% of total funding).

✓ **165 Ukrainian organisations** (0.71% of all participating organisations) became members of the HE.

HEOinUA, NRFU has already provided 172 consultations, organised and participated in 117 events, which has increased the success rate of Ukrainian participants in the HE.

The average success rate of participating countries is 17.19%.

[69]https://www.kmu.gov.ua/news/dva-roky-roboty-fondu-pidtrymky-enerhetyky-ukrainy-na-potreby-ukrainskykh-enerhokompanii-zibrano-ponad-410-milioniv-ievro-z-13-krain-ta-mizhnarodnykh-orhanizatsii

[70] https://eefund.org.ua/en/pro-fond-2/

[71] https://innovate-ukraine.b2match.io/

Today, Ukraine ranks 7th out of 18 associated countries in terms of the amount of funding received and 6th in terms of the number of participants. The information is according to the CORDIS. In addition to the Horizon Europe and Euratom programmes, Ukraine works within the EUREKA programme. Ukraine is a member of CERN, the Antarctic Treaty, and the SPS NATO Programme.

Under the EU's Horizon 2020 research and innovation programme, 168 Ukrainian organisations have implemented 228 projects totalling over EUR 45 mln. At the same time, 29 projects were coordinated directly from Ukraine.

Within the Euratom research and training programme over 2015-2020, 14 Ukrainian organisations implemented 19 projects of EUR 4.71 mln worth.

Since 2006, 193 Ukrainian organisations, together with international partners from 30 countries, have implemented projects worth a total of € 7.2 mln under the EUREKA programme.

Currently, Ukraine carries out active bilateral cooperation in the field of science and technology with 13 countries (Austria, France, Germany, Latvia, Lithuania, Poland, Slovakia, the Czech Republic, Israel, India, South Korea, China, USA) and annually implements more than 100 joint research projects. During 2021 were implemented 104 joint research projects with total financing of almost UAH 20 mln.

Ukraine has been cooperating with NATO in the field of science since 1991. Since 2014, Ukraine has been the largest beneficiary of NATO's Science for Peace and Security (SPS) Program. Every year Ukraine is a co-executor of about 30 projects.

Project Title	Description	Participants and Funding
GR4FITE3: Graphite Resilience for lithium-Ion battery anodes through a sustainable European End-to-End supply chain	Innovative graphite products for lithium-ion battery anodes Graphite serves as the common choice for the anode in lithium-ion batteries. The EU-funded GR4FITE3 project aims to establish a sustainable end-to-end supply chain for European industrial graphite and carbon products. This is specifically targeted towards anode active materials used in lithium-ion batteries designed for electric vehicles and power sources like solar and wind farms. The supply chain encompasses responsible mining, energy efficient upgrading, and the incorporation of recycled and synthetic graphite, as well as silicon nanoparticles. These elements combine to form a distinctive anode active material. The consortium is composed of 10 partner organisations spanning six European countries, bridging the gap between industry and academia. The beneficiaries of this endeavour are an electric bus manufacturer and a utility grid developer.	LIMITED LIABILITY COMPANY ZAVALIVSKIY GRAPHITE Net EU contribution € 596 625,00 KYIV NATIONAL UNIVERSITY OF TECHNOLOGIES AND DESIGN Net EU contribution € 1 004 010,00 THE GAS INSTITUTE OF THE NATIONAL ACADEMY OF SCIENCES OF UKRAINE Net EU contribution € 1 023 638,75
BIOMETHAVERSE: Demonstrating and Connecting Production Innovations in the BIOMETHAne universe	New cost-effective biomethane production routes delivering greater yields The EU-funded BIOMETHAVERSE project aims to diversify the technological basis for biomethane production in Europe, increasing cost-effectiveness and contributing to the uptake of biomethane technologies. To this end, five innovative biomethane production pathways will be demonstrated in five different European countries: France, Greece, Italy, Sweden and Ukraine. In the BIOMETHAVERSE demonstrators, CO2 effluents from anaerobic digestion or gasification and other intermediate products will be combined with renewable hydrogen or renewable electricity to increase the overall biomethane yield. All demonstrated production routes consider a circular approach for energy and material use. The demonstrated technologies will reach TRL 6-7.	BIOENERGY ASSOCIATION OF UKRAINE Net EU contribution € 100 250,00 PrJSC "MHP EKO ENERGY" Net EU contribution € 957 120,50
HYDEA: HYdrogen DEmonstrator for Aviation	Hydrogen propulsion system for aviation Hydrogen (H2) is considered the most promising zero-emission technology to reduce aviation's	NATIONAL AEROSPACE UNIVERSITY KHARKIV AVIATION INSTITUTE NAMED BY N ZUKOVSKIY

	climate impact by 2035, in line with the European Green Deal and Clean Aviation Strategic Research and Innovation Agenda (SRIA). In this context, the EU-funded HYDEA project proposes a robust and efficient technology maturation plan to develop an H2 propulsion system. The project will comprehensively demonstrate the feasibility of hydrogen propulsion on an aircraft engine in a compacted timeframe (2023-2026) up to the ground test. HYDEA will address fundamental questions for hydrogen as an aviation fuel, including emission studies and technologies, and pave the way for the development and certification of new products integrating hydrogen technology.	Net EU contribution € 602 250,00
TWISMA: Twinning with ISMA to develop innovative calorimeters for high energy physics based upon advanced scintillation materials	TWISMA's overall aim is to boost the scientific excellence and innovation capacity of the Institute for Scintillation Materials (ISMA) and its high-quality Twinning partners - CERN and Institute of Light and Matter – to develop innovative calorimeters for high energy physics (HEP) based upon advanced scintillation materials. To achieve this aim, TWISMA will implement a research and innovation strategy over three years based upon five objectives implemented via five corresponding WPs. Objective 1: Conduct exploratory research on innovative calorimeters for HEP based upon advanced scintillation materials The objective is to develop a prototype homogeneous calorimeter based upon bismuth germinate-silicate oxides plus a prototype sampling calorimeter based upon Ce-doped garnet fibres. Both calorimeters for application in HEP.	INSTITUTE FOR SCINTILLATION MATERIALS OF NATIONAL ACADEMY OF SCIENCES OF UKRAINE Net EU contribution € 749 500,00
RESPONSE: integRatEd Solutions for POsitive eNergy and reSilient CitiEs	The EU-funded RESPONSE project aims to establish a strategic vision for Smart Cities Energy Transition: Climate-neutral cities by 2050 and supports two Lighthouse Cities and six Fellow Cities across Europe in delivering positive energy blocks and districts. Specifically, it will aim to achieve a local renewable energy systems penetration of 11.2 GWh/y, energy savings of 3 090 MWh/y and an emission reduction of 9 799 tons CO2 eq/y within the districts of the two Lighthouse Cities. The idea is to turn energy sustainability into a doable vision	REGIONAL DEVELOPMENT AGENCY OF LUGANSK REGION Net EU contribution € 246 000,00 ISOLUTIONS LLC Net EU contribution € 342 300,00

	by solving the energy trilemma (security, equity/affordability, environmental sustainability) at building, block and district levels in smart cities. The focus will be on heating and cooling systems, optimising energy flows with novel storage systems and linking with existing applications and other digital infrastructure. RESPONSE supports the lighthouse cities of Dijon (FR) and Turku (FI) and their Fellow cities Brussels (BE), Zaragoza (ES), Botosani (RO), Ptolemaida (GR), Gabrovo (BU) and Severodonetsk (UA).	
SUN4Ukraine: Sustainable Urban Net Zero Network for Ukraine	SUN4Ukraine aims to bring together Ukrainian cities with the EU 100 Climate Neutral and Smart Cities Mission, through capacity building, technical expertise, twinning, multi-level governance and policy to support them in adopting climate neutrality targets and incorporating climate neutrality into reconstruction plans. SUN4Ukraine will select and work closely with 10 Ukrainian frontrunner cities who will receive technical support and participate in a capacity building programme to develop Climate Neutrality Plans, aiming for climate neutrality by 2050. SUN4Ukraine will bring increased visibility to the Cities Mission and achieving its second objective of all European cities becoming climate neutral by 2050.	RO3KVIT URBAN COALITION FOR UKRAINE Net EU contribution € 272 250,00 CENTRE FOR ENVIRONMENTAL INITIATIVES 'ECOACTION' Net EU contribution € 210 562,50 PRIVATE INSTITUTION UNIVERSITY KYIV SCHOOL OF ECONOMICS Net EU contribution € 258 387,50 TSENTR DOSLIDZHENNYA SUSPILSTVA - CENTRE FOR SOCIETY RESEARCH Net EU contribution € 136 375,00 ALL-UKRAINIAN ASSOCIATION OF LOCAL GOVERNMENT AUTHORITIES ASSOCIATION OF UKRAINIAN CITIES Net EU contribution € 181 500,00

Table 11: Energy related project success stories in Ukraine

Cases

Case 1. ZenMo - Pioneering Simulation for Zero-Emission Transition

Country: The Netherlands
Innovation Ecosystem: South Netherlands Innovation Ecosystem
Innovation area: energy management systems

Key Innovation:
ZenMo's key innovation is its advanced simulation tools, which they call Virtual Labs (source). They model zero-emission transportation and energy systems, like a digital twin. The company leverages algorithms and data analytics to predict the outcomes of projects, providing stakeholders with actionable insights to guide their decision-making processes in the transition to sustainable energy and mobility solutions. They operate three simulation tools, the Energy Transition Lab, which can simulate a region`s energy system, that can contain heating supply, electricity supply, distribution and storage. The algorithm makes use of geographical data. The Spark City Lab simulates a smaller area: a city or a business park. It looks at both energy and mobility. Finally, the Smart Mobility Lab simulates freight and passenger transport. It can for instance compare the benefits of electric truck fleets with hydrogen truck fleets,

Implementation of Innovation & Practical Examples:
ZenMo works together with the province of Noord-Brabant in The Netherlands to create an Energy Transition Lab that simulates the energy supply of the province with the associated costs and CO2 emissions. The province uses this tool to test different future scenarios and create understanding amongst the stakeholders. (Source)
Besides local governments, the company also works together with DSOs. A case example is a project on the influence of smart charging on congestion in LV-grid for ElaadNL. The project assesses the influence of new technologies like electric transport, PV and heat pumps on the low voltage network. ElaadNL has conducted extensive research about the influence of smart charging on the congestion in low voltage grids using SparkCity, one of ZenMo`s simulation lab (source)

Incentives for Stakeholders:
Stakeholders, including municipalities, transportation companies, grid operators (DSOs) and energy providers, are incentivized by ZenMo's solutions that promise enhanced operational efficiency, reduced carbon footprints, and compliance with increasingly strict environmental regulations. The ability to simulate various scenarios before implementing costly changes provides a significant competitive advantage and reduces financial risk. In the energy field, having digital twin capabilities is exceptionally important, not only due to the financial incentives, but also because of the strict regulatory environment that hardly or does not allow real life testing that can lead to harm or temporary outages, as energy has to be provided 100% of the time.

Institutional Support/ Team Building, and Partnerships:

ZenMo's partners with Technical University of Eindhoven for research and development, and works together with multiple local governments to create a digital twin of their total, or part of their area.

Impact and Changes:

The main impact of digital twins and simulations created by ZenMo is that companies and municipalities can test zero-emission technologies that in the real world are not possible to test, without evidence or proof that they work efficiently. With ZenMo`s tools, these technologies can be tested and fine-tuned, so they perform better and have a chance for real world applications.

Results & Discussion:

ZenMo's approach has proven successful in various pilot projects, demonstrating significant potential to scale up and adapt to different industries and regions (Source). However, the complexity of integrating new data sources and adapting models to local conditions presents ongoing challenges. Future developments may focus on enhancing the adaptability of ZenMo's tools and expanding their application to other sectors, such as industrial energy management and residential energy optimization.

Case 2. Benefit for Balance - Revolutionising Energy Cost Balancing

Country: The Netherlands
Innovation Ecosystem: South Netherlands Innovation Ecosystem
Innovation area: energy management systems

Key Innovation:
The "Benefit for Balance" (BfB) initiative introduces a locally applicable alternative to the current market system, resulting in maximising local energy autonomy and minimising the load on the power grid. It rewrites the rules for local energy markets and optimises energy flows behind the meter (and eventually behind the group connection for energy hubs and collectives). Much smarter use is made of local potential. Within a local network, generation, storage and use are integrated with each other: from volume to value.

Implementation of Innovation:
The core of BfB's innovation lies in the implementation of a hyperdynamic incentive structure that is based on real-time local feedback of energy generation and use, rather than relying on national or regional forecasts. This system promotes efficient energy use and increases grid stability by reducing peak loads. By continuously balancing demand, storage and supply within a local grid, BfB drastically reduces traffic on the power grid. With BfB, energy is truly generated and consumed locally, contributing both to reduced a'naccessibility of large grid infrastructures and to making energy supplies more sustainable.

Example of Practical Solutions for Innovation Implementation:
In a pilot project in 2023 "Benefit for Balance" was integrated with the local grid, involving residential, commercial, and industrial participants. The system utilised advanced algorithms to analyse energy usage data in real-time, adjusting prices dynamically. This not only allowed consumers to take advantage of lower prices during off-peak hours but also helped stabilise the grid by encouraging energy usage when renewable production was high.

Incentives for Stakeholders:
Energy consumers were motivated by the potential for lower energy bills and more control over their energy expenses. Energy suppliers and grid operators were attracted by the possibilities for better grid management and reduced need for expensive grid enhancements. Furthermore, environmental stakeholders supported the project for its potential to increase the use of renewable energy.

Institutional Support/ Team Building, and Partnerships:
The "Benefit for Balance" project garnered support from the Municipality of Rotterdam sustainable energy initiatives and is currently securing funding from several green investment funds. Partnerships with local energy companies and technology providers were crucial in deploying the necessary infrastructure and ensuring the system's compatibility with existing grid operations.

Impact and Changes:
The pilot project demonstrated the following qualitative and quantitative impact:

- Sustainable Energy System: The model makes more efficient use of locally generated and stored renewable energy, contributing to a more sustainable energy system.
- Energy accessibility: Users become tens of percent less dependent on the central power grid, increasing their autonomy and resilience. This results in:
  - Continuous availability of power
  - Predictability of energy bills
  - Increased self-sufficiency in energy capacity, without the need to go completely off-grid
- Local resilience: the lights stay on through local integration of generation, storage and use system-level benefits: BFB contributes bottom-up to solving congestion problems on the grid, alleviating the investment burden for grid reinforcement by grid operators.
- Strengthening Local Storage: BfB promotes the business case for local energy storage, essential for the integration of renewable energy.
- Future Economic Benefits: With the removal of the net-metering scheme users can save up to €500 per year on energy bills.
- Community Level Optimisation: When applied at the community level at energy hubs or energy communities, locally generated energy is even better matched to local use. This increases the use of green energy and reduces the dependence on the central electricity grid significantly.

Results & Discussion:
"Benefit for Balance" transforms local energy markets and makes a substantial
contribution to making energy supply more sustainable. By strengthening local energy independence, strengthening and reducing the load on the central grid, it enables an important step towards a sustainable energy future.

Following the successful implementation of BfB behind the meter, the plan is to expand to community level with Energy Hubs and local energy communities. This approach reinforces the positive effects of BvB and responds to the increasing self-sufficiency of customers and falling margins in the energy market.

After its pilot phase, the scalability of the system across different regions with varying energy profiles poses an interesting challenge. Discussions have begun on how to adapt the system for larger environments, different energy market structures and on how to scale-up the current prototype.

Case 3. SADC & Hessenpoort - Creating a Sustainable Energy Hub

Country: The Netherlands
Innovation Ecosystem: West Netherlands Innovation Ecosystem
Innovation area: energy hubs

Key Innovation:
SADC (Schiphol Area Development Company) & Hessenpoort have collaboratively established an energy hub that integrates various renewable energy sources, digital technologies and storage capabilities to create a self-sustaining industrial zone. The main motivation is to avoid grid congestion related adversities, such as insufficient energy supply. This hub not only provides energy to local businesses but also contributes excess power back to the national grid, utilising advanced energy storage and management systems.

Implementation of Innovation:
The project commenced with the strategic goal of transforming the industrial areas of SADC and Hessenpoort into leading examples of sustainable energy use. The plan involved deploying a mix of solar, wind, and bioenergy technologies, coupled with state-of-the-art energy storage solutions to ensure a reliable supply and efficient use of generated energy.

Example of Practical Solutions for Innovation Implementation:
The energy hub includes large-scale solar parks, wind turbine installations, and biomass energy plants. These are interconnected through a smart grid that uses real-time data analytics to optimise energy distribution based on immediate demand and supply dynamics. The hub also features innovative energy storage systems, including batteries, heat storage systems and hydrogen fuel cells, to manage excess energy during peak production times (Source).

Incentives for Stakeholders:
Businesses operating within SADC & Hessenpoort not only benefit from reduced energy costs of up to 35% and enhanced sustainability credentials, but most importantly: have access to as much energy as they need (Source). Energy producers are incentivized by stable demand and the opportunity to test new technologies in a supportive and open environment. Local communities benefit from the creation of green jobs and reduced environmental impact (Source).

Institutional Support/ Team Building, and Partnerships:
The energy hub project at SADC & Hessenpoort received significant support from both national and regional governments through financial incentives like the SDE++ subsidy and regulatory facilitation. Collaborations with institutions such as TU Delft and the University of Twente provided cutting-edge research on energy storage and smart grid technologies. Key industry partnerships with Siemens, Vattenfall, and Tesla ensured the implementation of advanced solutions, including smart grid infrastructure, large-scale solar and wind installations, and efficient energy storage systems. Additionally, the project created green jobs and engaged the local community through educational programs.

Impact and Changes:
Since its implementation, the SADC & Hessenpoort energy hub has had a substantial impact on the region, leading to significant reductions in carbon emissions. For instance, the integration of large-scale solar parks and wind turbine installations has resulted in an estimated 20% decrease in CO2 emissions in the industrial zones. These renewable energy sources, combined with innovative energy storage systems like Tesla's Powerpack batteries, have enabled the hub to generate more energy than it consumes (source).
A concrete example of this impact is the hub's ability to contribute excess power back to the national grid, making it a net energy producer. The smart grid technology provided by Siemens allows for real-time optimization of energy distribution, ensuring that surplus energy is efficiently stored and redistributed during peak demand periods. This has not only stabilised the local energy supply but has also provided a reliable model for other industrial areas looking to adopt sustainable energy practices.
Additionally, the project's success has attracted international attention. The hub's design and implementation strategies are being studied and replicated in other parts of Europe and beyond, showcasing the feasibility and benefits of sustainable industrial zones. For example, a similar initiative is underway in the Port of Rotterdam, inspired by the successes seen at SADC & Hessenpoort.

Results & Discussion:
The success of the SADC & Hessenpoort energy hub illustrates the effectiveness of integrated renewable energy systems in industrial applications. However, the project also highlighted challenges such as the initial capital investment and the complexity of coordinating multiple energy sources and technologies. Future expansions will consider scalability and the integration of emerging technologies such as AI-driven energy management systems.

Case 4. Enerhash Ltd.– Energy Management Systems

Country: Hungary
Innovation Ecosystem:
Innovation area: Energy Management Systems

Key Innovation:
Enerhash, an innovative energy technology company, has developed a pioneering solution to harness stranded and flare gas resources for productive uses, primarily Bitcoin mining and high-performance computing (HPC) data centres. This case study explores Enerhash's innovative approaches, the practical implementation of their technology, and the resulting impact on the energy sector and the environment.

The core innovation by Enerhash involved the development of modular data centres, known as Databoxes, which utilise excess energy from stranded and flare gas resources. These data centres provide a decentralised solution for converting wasted gas into a valuable resource, thus addressing both economic inefficiencies and environmental concerns. The Databoxes offer flexible energy consumption,

enhancing grid stability and promoting the use of renewable energy sources by balancing supply and demand (Source) (Source) (Source).

Enerhash's technology also integrates blockchain for secure and transparent transactions, further enhancing the reliability of energy trading. This combination of blockchain and energy management technologies represents a significant advancement in the way energy resources are utilised and managed.

Implementation of Innovation & Practical Examples:
Enerhash's innovative approach was implemented through strategic partnerships and pilot projects. One significant project was the collaboration with Allied Energy and River Energy Group, focusing on utilising flare gas for Bitcoin mining. The initial 1 MW site at Allied's Thiel Well in Texas marked the first phase of a broader 20 MW development project. The data centres were designed to be integrated with gas treatment facilities and power generation infrastructure, showcasing the practical application of Enerhash's technology (Source) (Source) (Source).

Another notable implementation was in Sweden, where Enerhash deployed a 3 MW data centre using excess hydroelectric power from the Arctic Circle. This project optimised the utilisation of renewable energy and provided balancing services for the power grid, demonstrating the versatility and scalability of the Databox technology (Source).

Incentives for Stakeholders:
Enerhash provided multiple incentives for stakeholders, including energy producers, investors, and local communities. For energy producers, the Databox offered a profitable use for excess and stranded gas, reducing methane emissions and turning waste into revenue. Investors were attracted by the high returns and the cutting-edge nature of the technology, while local communities benefited from reduced environmental impact and the promotion of sustainable energy practices (Source) (Source).

Institutional Support/ Team Building and Partnerships:
Enerhash's success was significantly bolstered by institutional support and strategic partnerships. The company received funding from private investors and government bodies, which facilitated research and development. Key partnerships with major energy companies like E.ON in Europe and collaborative ventures in the USA and New Zealand helped Enerhash scale its operations and demonstrate the efficacy of its solutions. The company's leadership, including experienced professionals like Tamas Seregi, played a crucial role in guiding its strategic direction and fostering growth (Source) (Source).

Enerhash’s partnership with Allied Energy to utilise flare gas for Bitcoin mining is a prime example of how strategic alliances can drive innovation. This partnership not only provided the necessary resources but also validated Enerhash’s approach in the energy sector (Source).

Impact and Changes:
The impact of Enerhash's energy management system has been substantial. By converting flare gas into a resource for Bitcoin mining and HPC, Enerhash significantly reduced greenhouse gas emissions,

contributing to environmental sustainability goals. The technology also enhanced the efficiency of power plants and promoted the integration of renewable energy sources into the grid. This shift towards decentralised energy production and consumption empowered smaller producers and consumers, reducing reliance on large energy corporations and fostering a more resilient energy market (Source) (Source) (Source).

In Hungary, Enerhash's efforts have been instrumental in optimising power production. By deploying their data centres at various power plants, Enerhash has provided a stable source of income for these plants, making energy production more efficient and environmentally friendly (Source) (Source).

Results & Discussion:

The results from Enerhash's projects have been promising, demonstrating increased efficiency and profitability for energy producers. The successful implementation of the Databox technology in various regions highlighted its potential to revolutionise energy management by providing flexible, scalable solutions for energy storage and consumption. The discussions around these results emphasised the importance of continued innovation and collaboration to overcome regulatory and technical challenges. Enerhash's approach has set a precedent for future projects, showcasing the viability of integrating digital infrastructure with energy production (Source) (Source) (Source).

The use of blockchain technology further enhanced the transparency and security of energy transactions, making Enerhash's solutions even more attractive to stakeholders. This integration has not only improved operational efficiencies but also built trust among consumers and producers.

Enerhash's innovative approach to energy management demonstrates the significant potential of integrating digital technologies with traditional energy systems. By utilising stranded and flare gas resources, Enerhash has created a sustainable and profitable solution that addresses both environmental and economic challenges. The success of their pilot projects and strategic partnerships underscores the importance of collaboration and institutional support in driving innovation. As Enerhash continues to expand and refine its technology, it sets a benchmark for future advancements in the energy sector (Source) (Source) (Source) (Source) (Source).

Case 5. E.ON Flex.ON - Implement improvements to ensure the stability and resilience of the electricity network through innovative means

Country: Hungary
Innovation Ecosystem:
Innovation area: Energy Management Systems

Key Innovation:
Flex.ON is a complex programme involving several unique projects. The combined aim of the projects is to provide "smart" solutions to emerging energy market problems and to prevent and tackle potential future obstacles. The devices installed in the projects are designed to ensure the stability and flexibility of the power network. This program addresses the challenges posed by the increasing integration of renewable energy sources, such as solar power, which introduce variability in the grid. The key components of the Flex.ON initiative include the use of advanced technologies like In-line Voltage Regulators (IVR) and On-load Tap Changer (OLTC) transformers and energy storages to manage voltage fluctuations and enhance grid resilience. (Source, Source, Source[72])

Implementation of Innovation & Practical Examples:

The Flex.ON programme implements innovative technologies to maintain grid stability (Source[73], Source[74]):

1. **In-line Voltage Regulators (IVR):** IVRs are series transformers capable of balancing voltage increases and decreases. These devices autonomously regulate voltage within specified limits, protecting consumers from rapid changes and seasonal consumption effects. IVRs are particularly beneficial for long, heavily loaded low-voltage lines, providing a cost-effective alternative to traditional network expansions. The programme plans to install 19 IVR units in areas with voltage complaints or long, heavily loaded lines, where traditional solutions would be too expensive.

2. **On-load Tap Changer (OLTC) Transformers:** OLTCs are used to adjust voltage levels under load conditions. These transformers are already used in high-voltage networks and are being tested in distribution networks. They are effective in managing voltage fluctuations caused by the integration of small-scale renewable energy sources, such as rooftop solar panels. Three OLTC transformers have been installed around Lake Balaton to balance seasonal voltage differences.

[72] Zsófia Lilla, Bangó: Hálózati innováció, IVR/OLTC a hálózatban, Energetikai Szakkolégium, Latest download: 2022.03.10.
[73] Zsófia Lilla, Bangó: Hálózati innováció, IVR/OLTC a hálózatban, Energetikai Szakkolégium, Latest download: 2022.03.10.
[74] E.ON Sustainability Report 2022

These transformers help maintain voltage quality, especially in industrial areas with significant power fluctuations.

3. **Smart Meters and IoT Integration:** The Flex.ON programme also includes the deployment of smart meters and IoT devices to collect and analyse real-time data from the grid. This data is transmitted via a 4G network to a cloud service for validation and archiving. The insights gained from this data help in the dynamic management of the grid, ensuring that voltage levels remain stable even with increasing renewable energy integration.

Incentives for Stakeholders:

The Flex.ON programme offers several incentives for stakeholders:[75]

1. Cost Savings: By using advanced voltage regulation technologies, E.ON can avoid expensive network expansions and upgrades. This results in significant cost savings for both the utility and consumers.
2. Enhanced Reliability: Improved voltage stability and grid resilience lead to fewer power outages and better service quality for consumers.
3. Environmental Benefits: The integration of renewable energy sources helps reduce greenhouse gas emissions, contributing to environmental sustainability goals.

Institutional Support/ Team Building, and Partnerships:

The Flex.ON programme is supported by the Hungarian Ministry of Innovation and Technology (now the Ministry for Energy). Total cost of the investments to be made in the project are more than 5.3 million euros, with the Ministry of Energy co-funding 39%. This collaboration ensures that the programme aligns with national energy policies and goals. E.ON has also formed partnerships with technology providers and academic institutions to develop and implement the advanced technologies used in the programme. For example, the Energetikai Szakkollégium (College of Energy) provides research and development support, helping to optimise the performance of IVRs and OLTCs. (Source)

Impact and Changes:

The initial results of the Flex.ON programme are promising. The deployment of IVRs and OLTCs has demonstrated their effectiveness in managing voltage levels and improving grid stability. The use of smart meters and IoT devices has provided valuable data for real-time grid management, further enhancing the flexibility of the electricity network. The programme has also shown that innovative, cost-effective solutions can address the challenges posed by the increasing integration of renewable energy sources.

The Flex.ON programme serves as a model for other utilities looking to modernise their grids and improve service quality while supporting the transition to a more sustainable energy system. Future plans include expanding the use of IVRs and OLTCs to additional parts of the network and further integrating these technologies into a comprehensive grid management platform. By continuing to innovate and

[75] Zsófia Lilla, Bangó: Hálózati innováció, IVR/OLTC a hálózatban, Energetikai Szakkolégium, 2022.03.10.

collaborate with stakeholders, E.ON aims to create a more resilient, efficient, and sustainable electricity network for the future. (Source[76])

Results & Discussion:

The initial results of the Flex.ON programme are promising. The deployment of IVRs and OLTCs has demonstrated their effectiveness in managing voltage levels and improving grid stability. The use of smart meter and IoT devices has provided valuable data for real-time grid management, further enhancing the flexibility of the electricity network. The programme has also shown that innovative, cost-effective solutions can address the challenges posed by the increasing integration of renewable energy sources.

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[76] Zsófia Lilla, Bangó: Hálózati innováció, IVR/OLTC a hálózatban, Energetikai Szakkolégium, 2022.03.10.

[77] E.ON Sustainability Report 2022

Case 6. Kazán Community House - Impact on community development

Country: Hungary
Innovation Ecosystem:
Innovation area: Energy Management Systems

Key Innovation:
The Kazán Community House's key innovativeness lies in its newfound community-based ownership of the 1,000-square-foot house, which includes 11 separate rooms and 10 tenants. The project implemented an innovative approach in Hungary on managing the building's energy consumption and establishing an energy community with the active involvement of the building's tenants. This model enabled tenants to collectively own and manage the property, fostering a sense of shared responsibility and collaboration. By creating a communal structure for energy use and decision-making, the project promoted sustainable practices and efficient energy management. The cooperative ownership model also facilitated the implementation of shared renewable energy solutions, such as solar panels, and allowed for the democratic allocation of resources through an energy efficiency fund. This pioneering approach not only addressed immediate energy needs but also built a resilient, self-sustaining community dedicated to environmental stewardship. The savings generated from green electricity are allocated to an energy efficiency fund, reinvested in further improvements to reduce the building's energy consumption. The organisations forming the energy community, and jointly owning the solar panels, collaboratively decide on the utilisation of the energy efficiency fund. These strategies not only ensured sustainable energy management but also fostered community involvement and environmental responsibility. (Source, Source).

Implementation of Innovation & Practical Examples:
Initially, the owner began renovations at the building as a sole owner. During the energy crisis, it became clear that running a building with poor energy efficiency is very costly, so the focus of the initiative broadened to include a vision and understanding of whole building energy.
In the winter of 2022/23, they managed to halve the building's gas consumption by simply changing the way it is used and by changing attitudes, and since then they have also completed a complex energy renovation plan. The elements of this plan include the replacement of windows and doors, complete insulation of the façade and, in the future, a switch to a heat pump, which will be powered by solar generation. Besides the practical changes, there has also been a community organising part of the initiative (e.g.: a multi-speed tenant model has been developed, a community renovation fund has been started to be formed from the profits generated by the solar panel). (Source).

Incentives for Stakeholders:
The project involved the active participation of the 10 different tenants from the building, ensuring that operational decisions were made democratically. Tenants engaged in plenary meetings to discuss and decide on major development decisions and community organisational related questions, thus creating a horizontal decision-making process. This decision-making approach and the surplus generated by the

solar panels led to the establishment of an energy renovation fund, aimed at financing energy efficiency improvements. The project also implemented a multi-speed tenant model, allowing tenants to contribute and participate at varying levels according to their capabilities and resources. In this model, the benefits of cooperative-based energy production are captured locally, as opposed to corporate, profit-based energy production. (Source)

Institutional Support/ Team Building, and Partnerships:

The Community House project organised a public donation system to gather funding for the project, engaging the broader community in their efforts. This grassroots initiative was complemented by institutional support, as they successfully secured funding from the Ministry for Innovation and Technology and the National Research, Development and Innovation Office. The combination of public donations and governmental funding not only provided the necessary financial resources but also validated the project's innovative approach. This collaborative effort among the tenants and their ability to attract external support played a pivotal role in the successful implementation of their energy solutions. (Sources)

Impact and Changes:

Kazán Community House has installed a 36 kWp capacity solar PV system on the roof of the building, the proceeds of which will be used to build an energy community fund.

In response to the energy crisis, joint conservation measures have cut the building's energy consumption for heating by nearly half. (Source) As a result, the community centre has achieved 50 percent gas savings, but the current changing market and regulatory environment presents a challenge in developing an energy community.

The solidarity of Kazan is also reflected in the fact that from the beginning of the energy crisis, tenant organisations have tried to spread their increased overheads, taking into account the different resource situations of the different organisations. There is also a general solidarity fund in place to share the burden. The emphasis in the operation is not on increasing profits, so improvements are not made in order to charge higher office rents, but to allow the different organisations to operate in better conditions. (Source).

Results & Discussion:

Kazán Community House have installed a 36 kWp capacity solar PV system on the roof of the building, the proceeds of which will be used to build an energy community fund. The fund will be used for small and large energy efficiency investments in the Kazan building. Strategic decisions are made democratically, together with the organisations in Kazan, while the Kazan energy community is managed on a day-to-day basis by the building's operator, the Alliance for Community Realestate Development and the Gólya Cooperative. (Source)

Case 7. Advisor Scada - innovative energy efficiency tachometer

Country: Ukraine
Innovation Ecosystem: Northern Ukraine
Innovation area: energy management systems

Key Innovation:

Advisor Scada - is an innovative Ukrainian development based on an intelligent system, where each object after connection, entering its high-tech environment, receives real-time diagnostics of equipment life and key energy consumption indicators and the ability to effectively control them, which ensures a 30% reduction in resource consumption. Connection to the service is through a universal gateway for connecting a variety of equipment, regardless of brand, into a complex system, but controlled in a panel with a web interface. Advisor Scada offers ready-made solutions for its target audience, in particular, management companies, network retail, co-working, sports clubs, business centres and smart cities.

The innovation offered ensures a wide range of ***energy efficient services***, in particular:

- automatic collection and accounting of energy consumption indicators
- indicators monitoring the comfort of the premises
- installation of automation and optimal operation of equipment
- condition monitoring of technical equipment, systematisation of service
- setting up an object to comply with international standards
- analytical centre for the promotion of energy efficiency

It is worth noting that the innovation is quite flexible due to the diversified approach based on the customer's request. For example, some of them require solutions as a service (i.e. SaaS), where the effectiveness of the solution could be consumed without purchasing any equipment, only the service as a complex solution. Others, on the other hand, require energy devices that help manage energy efficiency and the service itself. In addition, the beginning of autumn 2024 will be a starting point for the introduction of the Building Energy Management Administration System (i.e. BEMS), which combines energy management and dispatching to achieve more effective energy efficiency.

Implementation of Innovation:

The trajectory of the Advisor Scada development, especially in the context of creating a Minimum Viable Product (MVP), had several key classic stages, in particular:

- **Identification of the problem** based on the previous experience while implementing projects in the building sphere.
- **Conducting research** to validate the problem and assess the demand.
- **Development of a clear concept of the product** that addresses the identified problem (product vision, roadmap development, determination of the resources (time, budget, team) needed).
- **MVP Development, testing and validation** (what is noteworthy is that the MVP of the project had three stages to become the most relevant solution which had to meet the changing needs and requirements on functionality of the target audience).
- **Development of a marketing strategy** to create awareness and attract initial users.

- **Long-term maintenance and evolution** (in a gradual and consistent way staying responsive to market changes & innovation agenda).
- **Sustainability track that** ensures the product remains viable and competitive in the long term (scaling up the product into the new markets, development of the product & service itself depending on the diversified customers' needs).

By following this trajectory, a product has effectively evolved from an initial concept to a mature offering that meets market needs and sustains growth.

Example of Practical Solutions for Innovation Implementation:
As a leading innovation market player in the field of energy management within the energy sector, Advisor Scada has been able to reach out to the various stakeholders and end users of the system. These include developers in the construction industry, the largest retail network in Eastern Europe, sports centres and commercial points of sale (sports shops, etc.), business centres and, in total, more than 100 projects for real estate in Ukraine implemented by the Advisor Scada team. By implementing all these projects, Advisor Scada is able to certify its high level of expertise in implementing on-site BEMS for real estate in Ukraine. The implementation of the largest retail energy management system in Eastern Europe as well as more than 5 years of experience in developing software+hardware cloud solutions for real estate prove one of the best expertise in energy efficiency on the Ukrainian market.

Incentives for Stakeholders:
Research and Markets estimates that the global SCADA market will grow from $11.2 billion in 2024 to $16.6 billion in 2029, at a CAGR of 8.3% from 2024 to 2029. The growth of the SCADA market is driven by the increasing importance of real-time data analytics for process optimisation and predictive maintenance, as well as the growing adoption of IoT technologies in the manufacturing industry. These figures are motivating key players in the energy sector to actively adopt SCADA innovation in their operations and building management.

Institutional Support/ Team Building, and Partnerships:
A strong partnership plays a crucial role in developing and scaling up an innovation in a market where it is not widely available. Therefore, gaining the support of the leading technical university in Ukraine - Igor Sykorsky Kyiv Polytechnic Institute is the scientific and technological recognition of the innovation. A memorandum of cooperation in the field of energy efficiency for scientific development was signed to create the Scada consultant. To support the development of innovation, the team of the Scada consultant received a grant from the programme for financing innovative Ukrainian projects in the field of energy efficiency and ecology. As an active participant in international initiatives, Advisor Scada won the competition for the most innovative energy efficiency projects in Ukraine within the Impact Force project organised by the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH in Ukraine. Participation in the joint project Ukraine Impact Project & ESMT Berlin allowed Advisor Scada (namely Advansys as a manufacturer) to enter the European market. These collaborations and partnerships with stakeholders within the Quadruple Helix model are just the beginning, as the successful implementation

of SCADA projects is impossible without the active participation of all representatives of the Quadruple Helix model.

Impact and Changes:

SCADA devices in the energy sector are integral to the broader innovation ecosystem. Their connectivity and interaction with various technological advancements enhance efficiency, security, and sustainability. Advisor Scada connects and improves the innovation ecosystem by the following:

Internet of Things (IoT) and Industrial IoT (IIoT) integration

- Advisor Scada integrates with IoT/IIoT devices, providing real-time data from a vast array of sensors deployed across the energy infrastructure in the real estate premises.
- IoT devices enable remote monitoring and control, enhancing the capability of SCADA systems to manage energy assets from anywhere.

Advanced data analytics and machine learning

- Utilising machine learning algorithms to analyse data from Advisor Scada systems for predictive maintenance, reducing downtime and operational costs.
- Energy Big Data collection as the advanced source of information.
- Advanced analytics provide insights that inform strategic decisions, optimising energy production and distribution.

Cybersecurity innovations

- Integration of AI and machine learning to detect and mitigate cybersecurity threats in real-time.

❖ **Renewable energy integration**

- Advisor Scada systems connect with smart grid technologies to efficiently manage the integration of energy efficient sources as well as renewable energy sources like wind and solar power.
- Advanced Scada systems (in case of Advisor Scada improvement) will be able to manage energy storage solutions, balancing supply and demand more effectively.

Smart metering and demand response

- Connection with smart meters to provide real-time monitoring of energy consumption.
- Integrating with demand response programs to optimise energy use during peak periods, enhancing grid stability and efficiency.
- Developing advanced dashboards that present complex data in a more accessible and actionable format.

Automating compliance reporting to adhere to regulatory requirements, reducing administrative burdens and ensuring timely submissions.

Ensuring SCADA systems are updated to comply with the latest industry standards and regulations.

Collaboration and innovation networks

- **Innovation Hubs and research institutions**: Engaging with innovation hubs and research institutions to stay at the forefront of technological advancements and implement cutting-edge solutions.

By connecting Advisor Scada as a sort of SCADA solution with these innovative technologies and practices, the energy sector can achieve greater efficiency, security, and sustainability, driving the transformation towards a more resilient and smart energy infrastructure.

Results & Discussion:

Implementing SCADA solutions in the energy sector can significantly impact the innovation ecosystem in several ways. The real-time data and automated processes contribute to operational excellence, driving the energy sector towards more efficient and reliable energy production and distribution. The ability to make informed decisions based on data analytics fosters a culture of innovation. It encourages continuous improvement and proactive management in the energy sector. By enhancing grid stability and enabling the integration of renewable energy, innovative SCADA solutions support the transition to a more sustainable and resilient energy ecosystem. Strengthening cybersecurity measures not only protects critical infrastructure but also builds trust and confidence among stakeholders, encouraging further innovation and investment in the energy sector. Cost savings and financial efficiency enable energy companies to reinvest in new technologies and innovation, creating a positive feedback loop that drives further advancements. The environmental benefits of innovative SCADA solutions align with global sustainability goals, positioning the energy sector as a leader in environmental stewardship. At the same time, it should be noted that the initial decision to implement the SCADA solution was very much incentivised by the regulatory requirements set by the government.

Case 8. FEAK Independent Energy Data Center

Country: Hungary
Innovation Ecosystem: National level
Innovation area: Energy management systems

Key Innovation:

As a background institution of the Ministry of Energy, the Independent Energy Data Center Ltd. (FEAK) was established in June 2023. Its main tasks include developing and implementing solutions to enhance supply security and promote the broader utilisation of renewable energy sources in the electricity sector.

The project's goal is to establish an Energy Data Service Platform (ENAP) aimed at collecting, analysing, and disseminating key energy data relevant to identified issues in the electricity sector. This platform will utilise artificial intelligence solutions, considering that current electricity networks are not equipped to integrate the increasing amount of weather-dependent renewable generation. Additionally, it aims to provide the flexibility needed to address voltage issues on the side of Distribution System Operators (DSOs) and contribute to the balance between production and consumption managed by the system operator, MAVIR (TSO).

The data centre is funded by DIMOP_Plusz-2.1.1 and 2.1.2-23-2023-00001 project.

Implementation of Innovation & Practical Examples:

- Enhancing energy supply security: Developing strategies and solutions to ensure a stable and secure energy supply.
- Promoting renewable energy: Facilitating the broader adoption and integration of renewable energy sources within the electricity sector.
- Data management and analysis: Collecting, managing, and analysing energy-related data to support decision-making and policy development in the energy sector.
- Supporting energy policy implementation: Assisting the Ministry of Energy in implementing energy policies, particularly those aimed at increasing the use of renewable energy and improving energy infrastructure.

Incentives for Stakeholders:

- Proposal for the use of modern technologies tailored to specific conditions.
- Developing an IT platform to consolidate all data, providing a comprehensive overview of consumption and production, and offering services based on this data.
- They propose regulations and technological requirements.
- Data is collected from diverse sources, processed using artificial intelligence, and visualised effectively.

Institutional Support/ Team Building, and Partnerships:

Collecting data from public institutions, allowing these entities to connect with each other for energy sharing purposes. Additionally, they recommend improvements for these institutions.

Impact and Changes:

In regions currently not being measured, they can still determine production levels, consumption, and network development needs. The FEAK advice on where and how to develop household power plants. They also provide guidance to distributors on where it is advisable to establish new transformer districts and increase capacity.

Results & Discussion:

By collecting and providing data, they facilitate a more coordinated operation and collaboration among sector stakeholders. However, effective implementation requires that the organisations involved are open to data sharing and integrating innovation.
Regarding the results: The result manifests in more effective decision support, energy savings, or more cost-efficient electricity procurement, among other benefits. FEAK project started it's operation in 2023 June, lasting until 2026 meaning that the results will be measurable on a later stage.

The project will involve developing a detailed feasibility study, designing IT systems, and creating cooperation agreements with relevant stakeholders. The platform will adopt open-source solutions and utilise a private cloud model for data management. The ENAP's implementation will likely result in enhanced data accessibility and quality, reduced operational costs for DSOs, and better alignment of energy production with actual consumption needs. Future steps include finalising technical specifications, establishing operational models, and ensuring long-term sustainability of the platform.

Overall, the ENAP project represents a major step towards modernising the Hungarian electricity sector through advanced data management and analysis, aiming to address current challenges and adapt to future needs.

Case 9. Energy Management in Dolyna Community

Country: Ukraine
Innovation Ecosystem: Sectoral
Innovation area: Energy communities

Key Innovation:

Creation of the Cellular Energy Network (SmartGrid) of the Dolyna Territorial Community. There are a bunch of organisations, which unite their efforts to introduce innovative approaches in order to increase the energy sustainability of a community. That is supposed to result in:

- Ensuring reliability and stability of electricity supply;
- Increasing energy efficiency;
- Reduction of technological losses;
- Integration of distributed generation;
- Reducing the cost of energy resources for consumers

The idea is to develop distributed energy network in the Dolyna community and, in particular, in the city of Dolyna, by building solar energy and other RES plants (community owned), connect community owned enterprises, budget organisations, households and businesses to the grid, create energy management centre to coordinate/balance production and consumption. The centre may be governed by an energy cooperative, or participating enterprise, or by the community authority itself[78].

Implementation of Innovation: key issues and challenges

Current legislation allows to introduce smart grid models, create energy cooperatives and balancing groups, but there is a need to make the right decision on the legal configuration of a particular model. The core actor of the Dolyna smart grid - the biggest consumer of electricity in the community – utility company Vodokanal. It has all necessary experience, engineering and technical personnel to start the process. In 2023, 16.2 kW and 140 kW solar power plants were installed, and another 120 kW solar power plant is planned to be built.

There are also plans to build power plants for social infrastructure – hospitals, kindergartens, schools and administrative buildings. The challenge is to optimise capacity for consumption for each building, to minimise flows to other facilities and, accordingly, minimise technological and financial losses in distribution networks.

In the near future, the construction of additional solar power plants with a total capacity of 846 kW and an energy storage station with a capacity of 4 MW on the territory of the community is also planned. A biogas plant with a capacity of 4 million cubic meters per year operates close to the city, production of natural and associated gas is carried out with the corresponding capacity of 138 and 5.8 million cubic

[78] https://e-b.com.ua/ROZPODILENA-GENERACIYA-ENERGETICNII-MENEDZMENT-I-M-DOLINA-YAK-JE-I-YAK-MAJE-BUTI-6312

meters for a year. Wind turbines with a capacity of 2 MW have been installed near the Dolyna, with plans for their further expansion. In addition, there are three block-modular boiler houses with all the necessary infrastructure on the territory of the community. There are power grids with a voltage of 110 kV.

All those objects are planned to be connected to the Energy Management Center and create one balancing group or join a large balancing group as a local subgroup. In order to plan purchases, it is necessary to understand the actual level of consumption by each building and predict changes depending on weather conditions, day of the week, and other factors. For preliminary calculations from open data on energy management and demand management, typical profiles were compiled for the main community owned consumers (excluding households) of the city of Dolyna.

On the basis of the typical profiles of consumers and the generation profile of SES in this region, preliminary profiles of consumption and necessary generation of SES were established, with the compilation of balances of flows between the distribution system and the totality of utility budget consumers[79].

Background: Why is Dolyna the best choice for a pilot project?

Firstly, the size of the Dolyna territorial community of Ivano-Frankivsk region, which covers an area of 20.22 square meters. km with a population of 21,100 residents as of the beginning of 2022. World experience proves that the successful development of pilot projects for the implementation of such "smart systems" is significantly more effective when implemented in small communities compared to megacities.

Secondly, significant achievements in the field of energy and successful experience of energy managers in the community. In 2008, the city of Dolyna was one of the first in Ukraine to develop an energy saving strategy until 2020, and thanks to the successful implementation of a number of projects in the field of energy saving and the introduction of new best practices, it acquired the status of an indisputable leader in the field of energy efficiency.

The chronology of the implementation of projects in the Dolyna community shows the gradual and systematic development of RES in the community.

2009 - an agreement of mayors was signed in Brussels, under the terms of which the city undertook to reduce the consumption of basic energy resources and CO2 emissions by 20% by 2020 and increase the use of alternative energy sources by 20%.
2011 - the Action Plan for Sustainable Energy Development of the City of Dolyna (SEAP) for 2011-2020 was approved. This Plan made it possible to systematically implement energy efficiency measures, to create an energy management unit within the structure of the city council, and to install the "Energoplan" software for monitoring the consumption of energy resources of budget buildings.
2011-2012 - with "Kyoto funds" the city of Dolyna carried out complex thermal modernization for 4 preschool educational institutions: and for 2 health care institutions.

[79] https://e-b.com.ua/ROZPODILENA-GENERACIYA-ENERGETICNII-MENEDZMENT-I-M-DOLINA-YAK-JE-I-YAK-MAJE-BUTI-6312

2012 - within the framework of the European Union project "Support of energy efficiency projects in small towns of Ukraine" in Dolyna, a comprehensive thermal modernization of the local history museum was carried out. The cost of the project is 1.6 million hryvnias, of which 1.26 million are from the European Union, and the rest is from the city budget.
2015-2019 - as part of the SUDeP program, 30 multi-apartment residential buildings were insulated (the project budget was 1 million euros, which made it possible to reduce gas consumption by 23-36%). Three kindergartens are equipped with solar collectors. Also, more than 30% of budget sector buildings have been converted to heating with alternative energy sources (solid fuel).
2016-2018 - windows and doors were replaced in 94 apartments in multi-apartment residential buildings for a total of UAH 1,830,000 by co-financing (50% - city council funds and 50% - residents' funds).
2021 - Dolyna confirmed its strategic goals for the second stage of the implementation of the SEAP within the framework of the Agreement of Mayors and undertook to reduce CO2 emissions by 30% by 2030 and set itself the goal of achieving climate neutrality by 2050. (source)

Regarding the successful history of RES installations and energy efficiency improvements in Dolyna community, it is no wonder that the head of the energy-efficient city of Dolyna, Ivan Dyriv, expressed interest in the idea and supported the creation of a cellular energy network.

Figure 12: Available RES

Figure 13: Planned RES

Abbreviations:
WPS – wind power station
SPS - solar power station
HPP - hydro power plant
(Source – Project description by Leonid Unigovskyi, Naftogazbudinformatyka).

Incentives for Stakeholders:

There are 60 budget organisations (total 1777 Mwt capacity), 144 municipal companies (total 2507 Mwt capacity), and 8025 households' consumers (total 34171 Mwt capacity), in Dolyna city. They consume approximately 41 mln kilowatt-hours per year. (Dolyna hromada consumes approximately 125 mln kilowatt-hours per year)[80]. The concept aimed to satisfy the growing demand of consumers regarding security of supply, up to the ability of the network to operate in the energy island mode for a certain period.

There is a leasing scheme considered for participants. Each sublessee (hereinafter the recipient) under the terms of the contract can consume a certain amount of generated electricity (contractual amount) free of charge and execute the cooperative's commands regarding demand management. All electricity produced by the recipient in excess of the contractual amount is transferred to the cooperative. This is, according to the presentation of the group of experts of the Ukrainian National Committee of SIGRE under the chairmanship of Mr. Serhiy Kucher "Potential of consumer demand management in balancing the energy system of Ukraine", - reducing the amount of payment for energy resources consumed, as well as "receiving income ... for certain behaviour" ... of consumers ... "in the daily schedule of electricity consumption".

If the recipient consumes more than the contracted volume, he can purchase additional electricity from the cooperative (the price may be dynamic depending on time). All electricity produced by the recipient on subleased equipment in excess of the amount specified in the contract is the property of the cooperative.

The cooperative can:

- sell (transfer) this electricity free of charge (at a reduced rate) to members of the cooperative;
- sell this electricity to the market with the help of a trader (perhaps at a "green" tariff);
- receive additional payment due to the provision by the cooperative (cooperative management centre - aggregator) of auxiliary services and balancing services within the framework of CEM.

However, it is the decrease in the price of electricity for the water utility that leads to a decrease in tariffs for water supply and, accordingly, reduces the expenses of each resident of the community. Reducing the cost of electricity for budget institutions allows the community to save on these items of their budget expenses and direct the freed funds to finance the most urgent needs, for example, additional financing of public transport, hospitals, insulation of public buildings, modernization of water supply - the list can be continued

Institutional Support/ Team Building, and Partnerships:

Key Project participants-initiators are NAFTOGAZBUDINFORMATYKA LTD, "SCIENTIFIC & TECHNOLOGY COMPANY ENPASELECTRO" LTD, and ASTERS LAW FIRM. The concept titled «Creation of the Cellular Energy

[80] https://e-b.com.ua/ROZPODILENA-GENERACIYA-ENERGETICNII-MENEDZMENT-I-M-DOLINA-YAK-JE-I-YAK-MAJE-BUTI-6312

Network (SmartGrid) of the Dolyna Territorial Community» is protected by copyright certificate CR0647190624. The partnership of organisations has got support of the local self-government bodies of Dolyna territorial community, Ivano-Frankivsk Regional Military Administration, the regional centre of local and regional authorities of the Ivano-Frankivsk Region, the Ministry of Energy of Ukraine and the Office of the President of Ukraine (Sources)

Impact and Changes:

The advantage of installing solar power plants includes ensuring continuous water supply, reducing the load on the energy system and reducing electricity consumption, which leads to savings in budget funds on energy carriers. The expected planned amount of generated electricity is 130,760 kWh per year, which will lead to savings of budget funds, approximately, in the amount of 950 thousand hryvnias annually based on the current electricity tariff.

Economic benefits:

- External parties: economic benefits to external parties will steam from import substitution. The project will reduce reliance on imported fuel and electricity, thereby strengthening Ukraine's energy security.
- Customers: benefit from more reliable and cost-effective energy supply, enhancing their economic stability and growth potential.
- Supply chain: local suppliers of energy equipment and technologies can experience increased demand, potentially leading to job creation and revenue growth.
- Broader industry: by advancing smart grid technology and distributed generation, our project contributes to the industry's modernization and efficiency, which can positively impact economic productivity.

Government priorities: the project aligns closely with the Government of Ukraine's strategic priorities, as outlined in the "Concept for the Implementation of Smart Grids in Ukraine until 2035." This national strategy seeks to modernise the energy sector, and our project actively contributes to its realisation. Additionally, our efforts resonate with the Ministry of Energy's focus on smart grid technology, renewable energy integration, and community-based energy "hubs" as outlined in their development concept. These alignments reinforce our commitment to advancing Ukraine's energy industry.

Environmental impact: the project delivers positive environmental impacts by promoting the utilisation of local renewable energy sources. This reduces carbon emissions and supports Ukraine's transition to cleaner and more sustainable energy solutions, contributing to improved air quality and reduced environmental degradation.

Regional Impact: the project enhances energy supply stability and efficiency in territorial communities on a regional level which, in turn, can attract investments, stimulate economic growth, and improve the overall quality of life in the region.

Social Impacts:

- Lives Impacted: The project positively impacts the lives of residents in territorial communities by ensuring a reliable and sustainable energy supply, enhancing their daily quality of life.
- Jobs: Job creation may occur in various sectors, including energy equipment manufacturing and installation, safeguarding existing jobs, and potentially creating new opportunities.
- Education: The project can contribute to education by raising awareness about smart grid technology and renewable energy solutions, fostering a more energy-conscious society.
- Public Empowerment: By ensuring stable and affordable energy access, the project empowers communities, making them more resilient and self-reliant.
- CO2 Avoidance: by reducing reliance on fossil fuels, the project aligns with global efforts to combat climate change.

Results & Discussion:

Cellular Energy Network Dolyna will serve as a pioneering project in Ukraine, offering an opportunity to explore the synergy of efficiency and develop technical solutions that can be replicated in communities and cities across the country. The project underscores the team's dedication to address the country's energy recovery needs through innovative, low emissions, secure and accessible energy solutions, ultimately contributing to a cleaner, more secure, and sustainable energy future for Ukraine.

Case 10. Empowering Communities and Energy Resilience Zhytomyr region

Country: Ukraine
Innovation Ecosystem: Regional level
Innovation area: Energy communities

Key Innovation:

Solving the problem of finding large, sunlit areas while ensuring the energy resilience of the community is achieved through the innovative use of floating solar power plants. These installations, mounted on floating pontoons, provide a dual solution by optimising sunlight exposure and increasing the energy resilience of the community. This is a novel solution for Ukraine, although this technology has already gained supporters in other countries.

Implementation of Innovation: key issues and challenges

In 2018, Zhytomyr became the first city in Eastern Europe to announce the transition to renewable energy sources by 2050. That same year, Zhytomyr signed a memorandum of cooperation with the international

climate organisation 350.org. In 2019, the Zhytomyr community joined to the Global Covenant of Mayors for Climate & Energy[81] and committed to reducing CO_2 emissions in its territory by at least 30% by 2030.

Scientists from the Institute of Economics and Forecasting of the National Academy of Sciences of Ukraine simulated four scenarios for the transition of Zhytomyr's energy system to 100% renewable energy sources[82]. To assess Zhytomyr's ability to switch to 100% renewable energy sources by 2050, simulations of four energy development scenarios were carried out using the specially developed TIMES-Zhytomyr model, which is based on the national TIMES-Ukraine model. The scenarios for the transition to 100% renewable energy sources involve transforming Zhytomyr's energy industry by 2050 and contain a single comprehensive goal: to meet energy needs in the sectors of final energy consumption exclusively with renewable energy sources. This transition will significantly strengthen the energy independence and climate policy of Zhytomyr. At the same time, the growth of citizens' well-being must be ensured through reliable energy supply and energy security, as well as economic, environmental, food, and other forms of security. Modelling showed that Zhytomyr can technically switch to 100% renewable energy sources by 2050, requiring 2.1 to 2.8 billion Euro over the entire period, depending on the chosen scenario. According to estimates, achieving this goal necessitates annual investments of about 100,000 Euros.

The development of solar energy requires well-lit, large areas. Using large agricultural lands for this purpose is often impractical and sometimes very expensive. Although floating solar energy installations are still more expensive than conventional ones, they offer certain advantages. The sun's exposure during the day is usually slightly longer on water than on land, and the proximity to water helps cool the panels. According to B. Pakholiuk from Zhytomyr Agancy, Zhytomyr is currently developing project documentation for the construction of floating solar power plants, which not only generate electricity but also address the ecological problem of lake blooming.

Example of practical solutions

With the goal of becoming a "green" and energy-saving city, the city government of Zhytomyr conducted an energy and environmental audit of its infrastructure. As a result, the city received the "European Energy Award" certificate. This achievement also made it possible to attract EUR 63 million in loans and EUR 24.7 million in grant funds from various international organisations, including the European Bank for Reconstruction and Development, SIDA, GIZ, and the World Bank.

Zhytomyr became the first Ukrainian city to completely switch to LED street lighting, reducing electricity consumption by 50%, or 1.7 GWh per year. In 2021, a new CHP plant that runs on biomass and RDF fuel (fuel produced from various types of waste, such as commercial, industrial, or solid household waste) was launched. The construction was funded by EUR 9 million of private investments. The plant's capacity is 100,000 tons of garbage per year, producing 36,000 tons of RDF fuel. Consequently, the Zhytomyr Biothermal Power Plant will be fully supplied with new fuel produced from garbage.

[81] *Global Covenant of Mayors for Climate & Energy https://www.globalcovenantofmayors.org/*
[82] *Analytical Paper "Model Scenario Assessments of Zhytomyr City's Transition to 100% Renewable Energy by 2050" https://zt-rada.gov.ua/files/upload/sitefiles/doc1619525338.pdf*

Zhytomyr are planning to build another CHP plant with a capacity of 30 MW of heat and 7 MW of electrical energy (using wood chips and RDF), reconstruct district boiler houses, and install two biofuel boilers with a total capacity of 6 MW and modular solid fuel boiler houses. The total cost of reconstruction and modernization is EUR 57.7 million.

Energy-efficient measures allowed the city not only to reduce the consumption of street electricity, gas, and CO_2 emissions by 40-50% but also to survive missile and drone attacks with less loss. Despite regular strikes, housing and communal services were delivered to residents with minimal disruption. In the event of an accident at one boiler room, heat was quickly supplied from another. The presence of 173 individual heat points minimised the consequences of damage to heat lines. The operation of the new thermal power plant and energy-efficient measures enabled the city to almost never turn off the lights in citizens' homes, even during blackouts. However, to comply with energy consumption limits, street lighting and public electric transport had to be temporarily suspended.

Brief outline of the key innovations

For large European cities, the measures implemented by Zhytomyr may not seem innovative. However, for small Ukrainian cities during wartime, this represents innovative leadership by local self-government. Managerial thinking and the desire to implement "green" innovation and investment projects during the war are indeed innovative. Key initiatives include:

1. Reduction of street lighting energy consumption through LED street lighting.
2. Construction of a bio-thermal power plant.
3. Design of a floating solar power plant.

The key innovation is a floating power plant. Floating solar power plants are arrays of solar panels placed on special floating platforms, and a special term, "floatovoltaics," has been coined to denote them. This method of installation solves the problem of land shortage. Additionally, legislation prohibits changing the status of agricultural lands, making it impossible to install solar power plants on them. Water surfaces have excellent reflection properties, so by installing double-sided solar panels that absorb reflected solar energy, it is possible to significantly increase electricity generation compared to similar solar panels on land.

Water can act as a natural radiator, reducing the temperature of the solar panel's surface, which helps avoid electricity generation losses caused by panel heating. Solar panels also create an additional ecological benefit by improving the condition of the reservoir. By covering the water surface, they reduce the volume of water evaporation, which is crucial for low-water areas. The lack of sunlight prevents the development of some algae, thereby keeping the water cleaner.

Discussion & Conclusions

The case of the Zhytomyr highlights the innovative and forward-thinking approach to achieving energy resilience and sustainability amidst challenging conditions. Implementing floating solar power plants

demonstrates a strategic response to the dual challenge of finding suitable land for solar installations and ensuring a stable energy supply. This solution, while relatively new in Ukraine, showcases how adapting existing technologies to local contexts can lead to significant advancements in energy infrastructure.

The strategy of transitioning to renewable energy sources by 2050 reflects Zhytomyr's commitment to sustainability and climate action. By joining international climate initiatives and committing to substantial CO2 reductions, the city positions itself as a leader in green energy transition.

The Zhytomyr exemplifies how small cities can lead in implementing green innovations and enhancing energy resilience, even under wartime conditions. The development and planned implementation of floating solar power plants are particularly noteworthy, addressing land scarcity issues while improving energy generation efficiency. This innovative approach, coupled with other energy-efficient measures, sets a precedent for other small cities in Ukraine and beyond.

In conclusion, Zhytomyr's experience underscores the importance of innovative leadership and strategic planning in achieving energy resilience and sustainability. The successful implementation of these initiatives can serve as a model for other regions, illustrating that even under challenging circumstances, significant progress towards green energy goals is achievable. The case of Zhytomyr thus provides valuable insights into the potential of small cities to drive significant environmental and energy-related advancements.

Case 11. FUERGY: Innovating intelligent energy storage and management services via smart battery solutions

Country: Slovakia

Innovation Ecosystem:

Innovation area: Energy storage and management systems

Key innovation:

FUERGY's key innovation is its smart energy storage solution (brAIn) and automated smart technology management solution (flexibility brAIn).

The brAIn solution manages energy storage using data and AI predictions to autonomously charge and discharge batteries using either local RES or energy from the grid in order to maximise savings, optimise energy sources, and create resilience. The solution consists of third party hardware parts such as batteries, inverters or BMS and FUERGY's proprietary Control unit and Power mergers as well as an energy management app on Fuergy's software platform.

The flexibility brAIn solution balances the load deviations of electricity suppliers via the intelligent management of energy sources and technologies with the potential for accumulation and regulation,

such as heat pumps, furnaces, tanks and reservoirs, heating and cooling systems (HVAC), compressors, electric vehicles, photovoltaic panels or other technologies.

Implementation of Innovation & Practical Examples:

FUERGY has deployed its solutions across Slovakia with installations in the National Football Stadium (source) and the Banská Bystrica industrial park (source) serving as examples of carried benefits to stakeholders.

In the National Football Stadium "Tehelné pole" , FUERGY completed a two-stage deployment, initially the flexibility brAIn solution to manage the stadium's heat pumps, and subsequently the installation of the smart battery storage brAIn. The flexibility brAIn solution provides 'non-certified ancillary services' to the grid - the services refer to the supply of regulation electricity at point of delivery or production without contractual commitment to availability for which the service providers are financially rewarded directly through their billing with their electricity supplier.

The flexibility brAIn automatically regulates the power output of the heat pumps within the parameters set by an overarching measurement and regulation (MaR) system. The brAIn smart battery storage also provides parallel non-certified ancillary services, using predictive algorithms supported by artificial intelligence to automatically optimising the storage capacity available for the power grid in the case of future surplus of electricity on the grid. The brAIn is not reducing electricity consumption but shifting production / consumption of electricity over time to balance the needs to the stadium and the grid. The two solutions are also able to work together to monitor and manage reserved capacity according to regulatory needs.

Incentives for Stakeholders:

FUERGY offers alternative business models for deployment of its brAIn technology according to the needs of its customers. For all FUERGY solutions the financial model applied is based on a success fee (share of the financial benefit leveraged by intelligent management of customer electricity) with financial benefits for all stakeholders, from the customer through to the energy supplier, FUERGY, and investors via a profit sharing model, with customers able to rent the smart battery storage brAIn from either FUERGY directly, the energy supplier SE, or a third party, in an energy as a service model.

Via the combination of non-certified and certified ancillary services offered by FUERGY's solutions, as well as the optimisation of existing RES assets, the solutions are able to achieve full ROI in as little as 2.4 years, with a battery lifespan of 15 years.

Zero initial costs, fast implementation, automated solutions, lower utility bills, improved green energy production and CO2 emissions reduction, energy self-sufficiency and non-stop protection against power outages are amongst the other key benefits.

Institutional Support/ Team Building, and Partnerships:
FUERGY has built strong working relationships with national energy suppliers such as Slovenské elektrárne (with specific products also having been developed for suppliers (mAInchart dispatch system), as well as with regulators and TSO representatives (a specific TSO-BSP interface has been designed)

Impact and Changes:

Beyond the financial impacts, from a climate lens the solutions allow more optimal and efficient management and use of local RES, as well as the displacement of existing fossil fuel based ancillary service reserves that the grid currently relies on.

By supporting the growth of battery and energy storage technologies, FUERGY is also driving the growth of a sector essential for the downstream widespread uptake of locally produced, renewable energy that can be managed at source.

Results & Discussion:
In the case of the National Football stadium, the benefits were optimisation of total energy costs (management and optimisation of the local RES as well as revenue from ancillary services), reduction of CO2 emissions (replacement of fossil-fuel based ancillary service providers with emission free alternative via heat pump capacity) with a demonstrated saving of approximately 265 tonnes of CO2e per year, reducing the stadium's CO2e emissions by 29%.

In the case of the Banská Bystrica industrial park installation, this was complete in only 6 months, with significant financial (conservative ROI within 3.5 years) and climate (eliminates 361 tonnes of CO2 emissions and pays off carbon debt in a year) results. Given the timeframe for ROI, and the technology lifespan is expected to be at least 15 years, the solution offers significant profit opportunity. In addition to the current certified and non-certified ancillary services offered to the grid, FUERGYexpect to add other ancillary services to their offering, as well as currently offering the ability for the park to optimise use of the solar panels on site. The solution is commercially viable and requires no subsidies.

Case 12. EINPARK: Carbon-neutral building via digital solutions and community engagement

Country: Slovakia
Innovation Ecosystem: Bratislava region
Innovation area: Energy management systems and community engagement

Key innovation:
As with many of the required cases for Slovakia's energy transition, EINPARK showcases not an innovative technology per say, but focuses instead on novel deployments and combinations of existing technologies, alongside social innovations and education, to achieve carbon neutrality. Einpark building was the first carbon-neutral building in Slovakia. The building's modern structure exemplifies contemporary architectural design and sustainable building practices including the integration of numerous digital solutions to optimise energy efficiency. Einpark has a sophisticated digital building management system that goes beyond traditional temperature setting but also focuses on the quality of air by monitoring CO2 levels. From the social side, Corwin focused on active communication and advocacy approaches, which include education of tenants on sustainable practices. The project is a result of Corwin Real Estate's commitment to enhancing urban living through thoughtful and responsible development. Corwin is renowned for its strong commitment to sustainability with a track-record of integrating eco-friendly practices into its projects, prioritising green building techniques, energy efficiency, and sustainable urban development including being the first local developer to publish an ESG report for the second year in a row. Similarly, Corwin has a focus on in-house innovation and the digital transition, being the first Slovak developer to fully digitalised flat handovers.

Implementation of Innovation & Practical Examples: Einpark building's sustainability credentials
Einpark is the only carbon-neutral building in Slovakia as it was specifically designed with sustainability at the core of the project. It incorporates energy-efficient systems and materials, aiming to reduce its environmental footprint. The project was ranked among the top 1% of the most sustainable buildings in the world.

- **Digitalisation:** One of the key innovations that contributes to better environmental impact, is the full digitalisation of Einpark building management. Such digitalisation includes: optimisation of outside shades usage for temperature, automatic lights, intelligent inside temperature optimisation, intelligent CO2 sensors in rooms, which propel more air-in if the CO2 levels get too high. Corwin team mentioned that building management is continuously improving and that they expect further improvements. Corwin states tha Einpark brings up to 77% energy savings and 51% water savings compared to conventional buildings. Einpark Offices is the most technologically advanced building in Slovakia and due to the use of progressive construction products and innovative construction procedures, it won the prize of the expert jury in the Construction of the Year 2020 - 2021 competition.

- **Cooling**: Einpark is built using cooling beam technology, which uses radiant cooling to ensure thermal comfort for people in the building and an environment that supports their higher productivity.
- **LEED Certification**: The building is constructed to meet LEED (Leadership in Energy and Environmental Design) standards, ensuring high performance in energy savings, water efficiency, and CO2 emissions reduction. Einpark is the first office building in Slovakia that was designed and built according to the highest certification criteria LEED Platinum.
- **Solar panels:** Solar panels are not present on the building. Corwin completed a suitability analysis with models. The decision was not to allocate any PVs as it would provide less than 1% of energy if used. The decision to omit PVs included the consideration that a significant portion of low carbon electricity available in Slovakia grid due to its nuclear and hydro energy focus.
- **Green roof**: The creation of a green roof was chosen as a more viable option for the building compared to PV. Vegetation on the roof prevents the building from overheating in the hot months and improves the surrounding microclimate. Corwin states that the microclimate around Einpark can thus be up to 2°C colder than in the rest of the city. The roof captures and utilises all the rainwater that falls on the property, thus significantly reducing the load on the sewage system and thus preventing flooding.
- **Electric composter**: Einpark has an electric composter that can process up to 50 tons of organic waste per year. The composter is used both by building management for maintaining the surrounding greenery, but also by the tenants.
- **Heat pumps**: The entire building is powered by large scale heath pumps. The infrastructure runs 18 meters deep and extracts cold water from the Danube. The water is used for both heating and cooling purposes.
- **Sustainable transport solution**: The building offers over 70 bike parking spaces and 7 charging stations for electromobiles.
- **Social initiatives**: Corwin activities go beyond just environmental considerations. When building Einpark, the social angle of sustainability was considered too. The building has direct access to public transport, via an allocated bus stop. The developer is targeting a behavioural change of Einpark tenants. Tenants are also provided with "sustainability manuals" produced by Corwin, providing them with practical tips on waste management or energy conservation.
- **Biodiversity**: Einpark's green roof is home to seven bee hives (350 000 bees) over a year. Since last year, the bees have produced 145kg of honey.
- **Tenants' sustainability preferences**: Mercedes-Benz, one Einpark's current tenants stated that sustainability credentials of the building played a key role in their decision to relocate to the building. Mercedes-Benz is targeting climate neutrality by 2039 and having the offices in Einpark helps their operational emission targets. The same rationale was used by other tenants such as Beiersdorf or McDonald's stating that the climate neutrality of Einpark was an interesting proposition for them since it combines cost saving and the company's sustainability objectives.

Figure 14: Results & Discussion: Einpark sustainability in numbers

The case highlights the importance of taking a multi-sector, multi-stakeholder approach to energy transition planning. Despite the real estate and construction sectors often being susceptible to lagging behind other sectors on sustainability, Einpark demonstrates the opportunities of integrated planning, leveraging existing technologies and creating significant benefits for end users and residents, as well as developers and solution providers alike. With the construction industry responsible for almost 40% of global emissions, increasing awareness of different solutions for a more digital, and sustainable industry is essential.

Ecosystem maps

Figure 15: Ecosystem map of Hungary

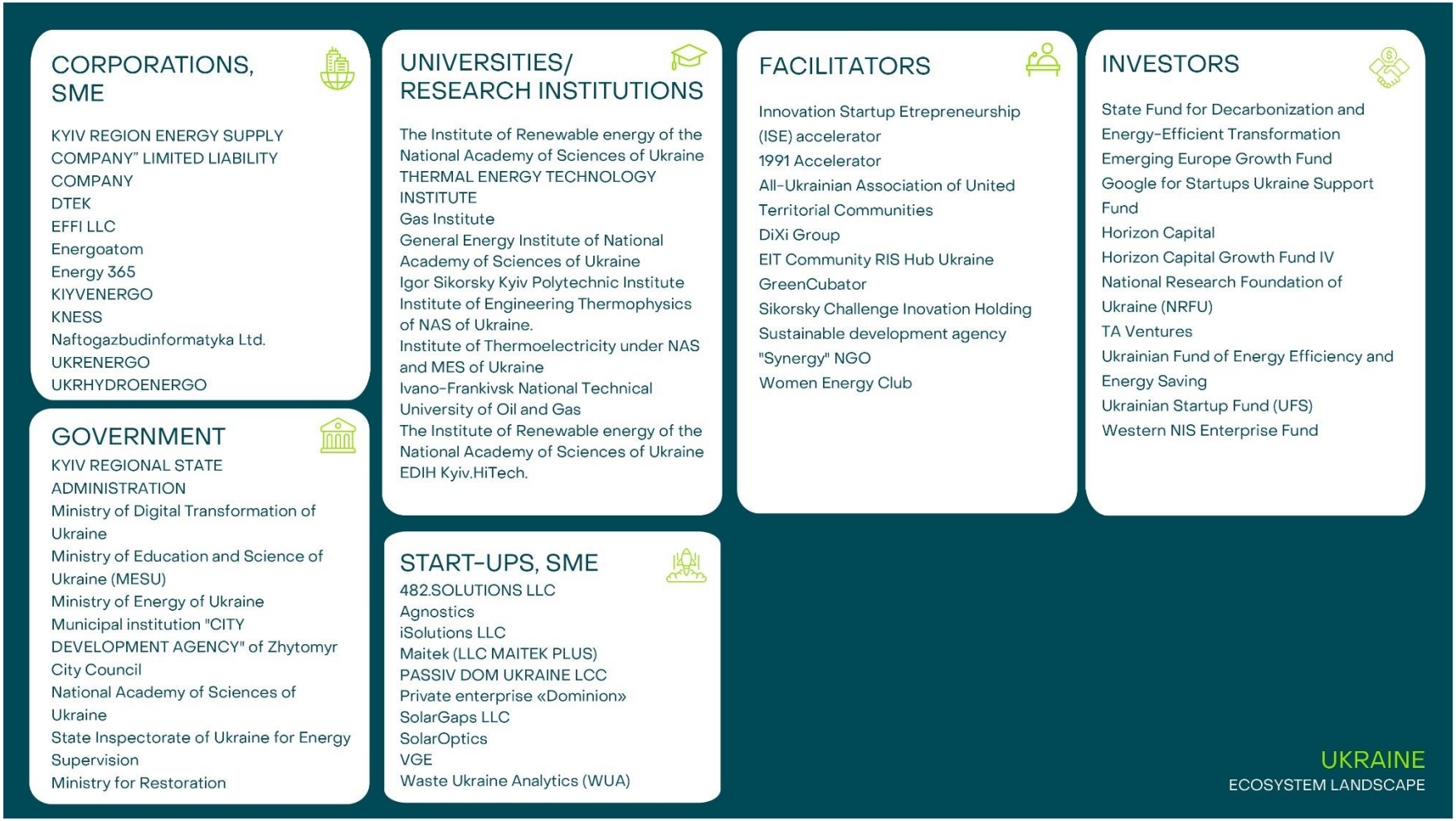

Figure 16: Ecosystem map of Ukraine

Figure 17: Ecosystem map of Slovakia

Figure 18: Ecosystem map of the Nether


wennovate