

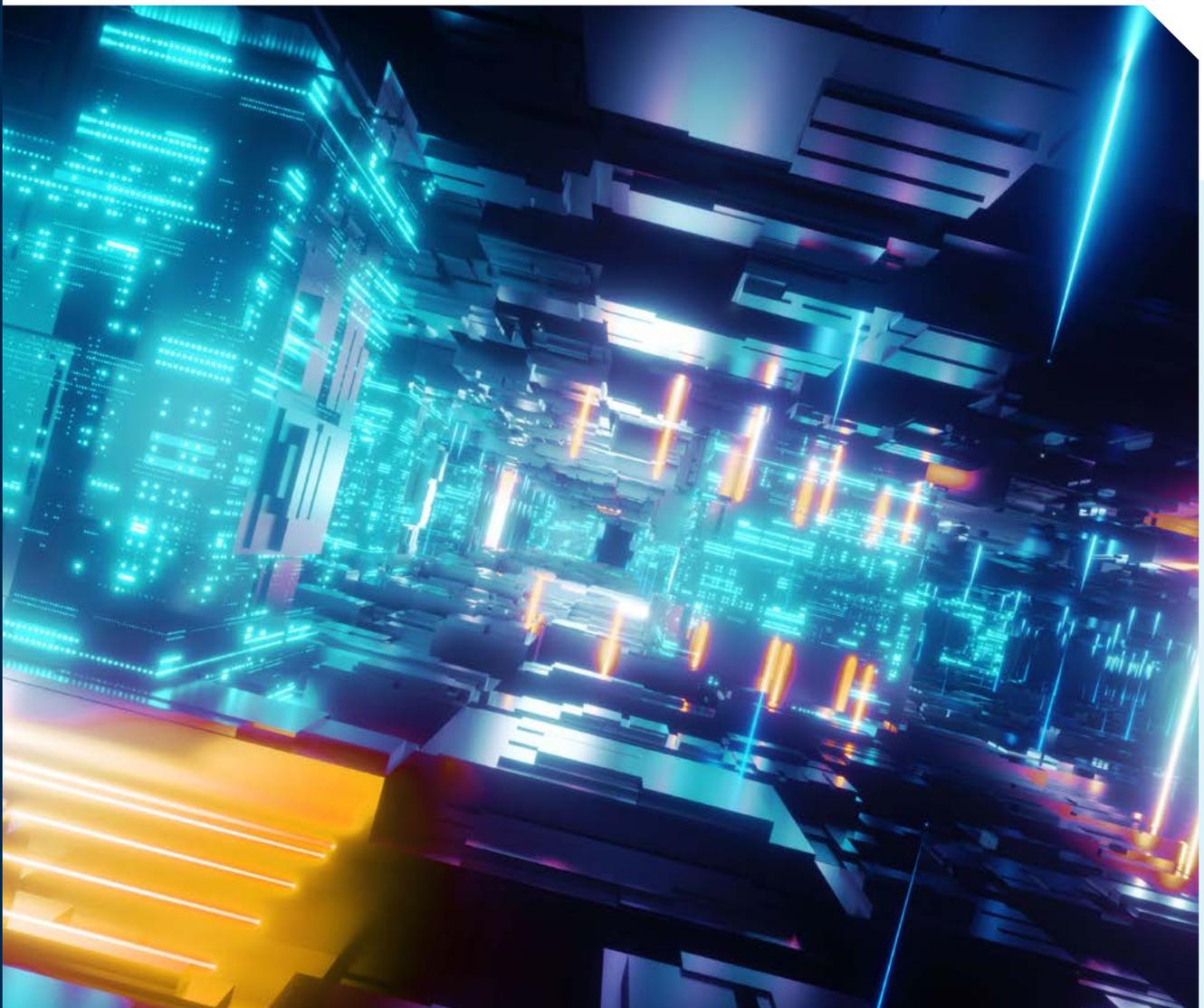


University of Vaasa
VAASAN YLIOPISTO

Energy for Sustainable Growth and Resilience



University of Vaasa White Paper



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 University of Vaasa White Paper | October 2025



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Foreword

The global energy transition is one of the defining challenges of our time. Climate change, geopolitical tensions, and increasing energy demand are reshaping how societies produce, distribute, and use energy. Achieving this transformation requires long-term commitment and collaboration across technology, business, and policy.



Finland has a unique opportunity to become a global frontrunner in clean energy innovation. The world urgently needs scalable solutions that not only mitigate climate change and strengthen the resilience of energy systems but are also attractive, efficient, and easy to implement.

Smart and flexible technologies are today's necessity – and this is where Finland and Europe have the potential to succeed.

The Vaasa region in Finland has already demonstrated what is possible. As home to the Nordic countries' largest energy technology cluster – with over 180 companies and organisations,

including global leaders such as ABB, Wärtsilä, Danfoss, Hitachi Energy and the University of Vaasa – it forms a strong ecosystem where research, innovation and growth meet.

The University of Vaasa and the companies in the Vaasa energy technology cluster have jointly launched the Energy Transition Valley initiative. The goal is to strengthen the region's research, development, and innovation activities with new research infrastructure, joint business-driven programmes, and a significant expansion in doctoral education.

This white paper presents the opportunities that arise as we

move towards smart, low-carbon solutions in energy production and consumption. A successful transition mitigates climate change, helps societies adapt to it, and generates new employment and economic growth while improving energy security. The University of Vaasa contributes to this transformation by combining expertise in energy technology with a deep understanding of business renewal, investment, and societal change – elements that are all essential for a sustainable energy future.

– **Minna Martikainen**
Rector, University of Vaasa

Summary

The energy transition is not only about climate action but also an economic, technological, and societal opportunity. It creates new jobs, drives growth, strengthens energy security, and offers Finland and Europe an opportunity to become leaders in clean energy technology.

A major growth opportunity

Europe must invest decisively in competence, technology, and infrastructure. Global investments in clean technologies are projected to reach EUR 2 trillion in 2025, while investments in fossil solutions are expected to be only half that amount.

Need for improved energy security

Following Russia's invasion of Ukraine, the reliability of energy supply became a core concern for Europe. The growing share of zero-emission energy sources diversifies energy production and strengthens domestic capacity, reducing dependence on fossil

fuels. At the same time, new technological solutions are needed to ensure grid stability.

Geopolitical competition and regional differences

Energy has become a tool of geopolitical and economic competition. The United States relies on its large fossil reserves, while China dominates the supply of critical minerals and leads the production of solar, battery, and electric transport technologies. Europe lacks such reserves but has a strong motivation to break away from Russian energy, directing investments towards renewables and nuclear power. The EU must promote a coherent yet flexible transition where legislation supports the scaling of innovation across the Union.

New jobs and shifting skills

According to the International Labour Organization (ILO), the transition to a greener economy could create 24 million new jobs by 2030, particularly in Asia, while

around six million jobs may disappear in carbon-intensive sectors. The transition therefore requires major investments in skills and education to ensure enough qualified professionals to implement the change.

The role of business, education and RDI

Long-term investment in competence is essential: interdisciplinary expertise and strong collaboration between universities, companies, organisations, cities, and regions are the foundation of a successful energy transition. To ensure this capability, the University of Vaasa educates new experts who master technology, business transformation, management, and societal change. Especially strong in business education, the university combines business and the energy transition in both research and education to support the transition to advance faster and on a broader scale.

Towards a cleaner future: the benefits of the energy transition

The energy transition is more than a response to climate change – it is an opportunity for economic, technological, and social transformation.

The energy transition is one of the defining economic opportunities of our time. Europe must seize it with determination. Sustainable growth calls for systematic investment in knowledge, skills, technology, and infrastructure.

Jobs and growth

According to the International Energy Agency (IEA), global investment in clean energy – including renewables, nuclear power and electrification – will reach about EUR 2 trillion in 2025, twice as much as investments in fossil fuels. Market dynamics are already driving the transition forward.

According to researchers Dutta, Bouri, Rothovius, and Uddin, climate risk has improved the returns of green investments and reduced price volatility. Green assets now serve as better hedges against oil market fluctuations than gold. As investors increasingly prefer sustainable options, the flow of capital further accelerates the transition.

Energy has also become a tool of economic and geopolitical competition. Although U.S. President Donald Trump's pro-fossil policies

may slow change domestically, they cannot reverse the global trend. The U.S. relies on its extensive fossil reserves, while China dominates the supply of minerals essential for electrification and leads global production in solar, battery, and electric mobility technologies.

Europe lacks similar natural resources but has strong incentives to free itself from Russian energy. According to S&P Global, Europe must increase investments in solar, wind and nuclear power to secure its position in the energy transition.

Asia in the lead – Europe with potential

The ILO estimates that the transition to a greener economy could create 24 million new jobs by 2030, most of them in Asia, while six million jobs may disappear in emission-intensive industries. Europe, however, holds vast potential: the European



Commission reports that the renewable energy sector already employed more than 1.6 million people in 2022.

Finland's technological opportunities

Finland's major opportunity in the transition lies in its strong expertise in electrical engineering and energy technology, developed over more than a century.

The Vaasa region, home to the Nordic countries' largest energy technology hub, includes some 180 companies and organisations. The cluster's key players are Wärtsilä, ABB, Danfoss, Hitachi Energy – and the University of Vaasa, whose research covers the essential areas of electrical engineering and energy technology.

Significant investment in competence

The U.S. think tank Center for Strategic and International

Studies (CSIS) notes that the transition will reshape the labour market: jobs linked to fossil fuels will decline, while those in clean energy will increase.

Companies in the Vaasa energy technology cluster invest around EUR 250 million annually in research and development. By 2030, regional investment in energy technology infrastructure is expected to rise to nearly EUR 1.9 billion. The University of Vaasa educates professionals and conducts joint research projects with companies, contributing expertise in technology, business, management, and governance – skills essential to leading change.

Key figures in the energy transition:

2 trillion euros
global clean energy
investments in 2025

24 million
new jobs created globally
through the energy
transition

180
companies and organisa-
tions in the Vaasa energy
technology cluster

€250 million
annual R&D investment
by Vaasa-based energy
technology firms

Energy security and its new challenges

The energy transition enhances security in many ways but also brings new risks. It must be supported through consistent investment in technology, infrastructure and preparedness.



Diversified domestic energy production strengthens supply resilience and reduces dependence on fossil fuels. Yet, according to the European Central Bank, energy shocks can still undermine corporate investment and productivity, weakening Europe's long-term competitiveness. Deeper integration of European energy markets and a faster green transition will, in turn, lower prices and strengthen supply stability.

After the war in Ukraine, energy security became a top concern across Europe. The European Commission has since launched initiatives to secure affordable energy supplies even during

crises, taking into account geopolitical tensions, cyber threats and extreme weather.

The United States also frames energy policy through a security lens. However, while the U.S. warns of "over-reliance on intermittent energy sources", Europe is investing in innovation and smart grids to strengthen resilience through renewables.

Vulnerability increases costs

Weather-dependent power generation makes grids more dynamic and vulnerable to failures. Grid architecture may expose

vulnerabilities to extreme weather conditions, vandalism and even terrorism. A recent power surge triggered cascading blackouts across Spain, Portugal, Andorra and parts of France.

Fortunately, protection methods are evolving rapidly. Professors Kimmo Kauhaniemi and Hannu Laaksonen at the University of Vaasa have called for stronger investment in grid resilience.

The University of Vaasa has participated in several projects developing smart and resilient solutions that enable real-time grid monitoring and faster fault detection.

Consequences of power outages:



Electricity price volatility causes financial losses.



Infrastructure failures demand costly, urgent repairs.



Business operations may be interrupted or halted.



Households face both insured and uninsured damage.



Health-care systems are disrupted, posing risks to vulnerable groups.



Critical infrastructure such as transport and water systems may fail.

In their research article, Syrmakesis and Hatzargyriou note that digitalisation introduces new risks to energy systems and that no universal protection model exists; rather, effective solutions depend on the system architecture, regulatory environment, and organisational capabilities.

Measures to enhance energy-system resilience:

- Build smart grids.
- Decentralise energy production.
- Develop renewable backup power systems.
- Improve electricity storage capacity.
- Develop microgrids capable of islanded operation.
- Establish cross-border electricity markets.
- Create balancing mechanisms to manage supply and demand.
- Strengthen demand-side flexibility and price responsiveness.

The energy transition mitigates existing risks while generating new ones

- The energy transition strengthens energy security through diversification and domestic production.
- Managing new risks requires not only technical solutions but also updated business and organisational models.

Towards a more sustainable society

While the United States continues to rely on fossil fuels, the transition is accelerating in China and Europe. The fight against climate change remains the key driver: investments in clean energy have doubled since 2020.

According to the World Economic Forum, annual global investment should reach at least EUR 5.5 trillion by the end of the decade. Encouragingly, Carbon Brief reported in 2025 that China's CO₂ emissions had declined for the first time – about one per cent lower than the previous year – largely due to record-breaking renewable capacity additions. Emissions in the energy sector have decreased particularly as China has invested heavily in solar, wind, and nuclear power.

In 2024, the country built almost twice as much new renewable capacity as the rest of the world combined.

The United States' fossil fuel-friendly policy has raised concerns about whether the global energy transition might slow down. However, climate change will not wait. Wildfires, floods, heatwaves, and other extreme weather events are already affecting many parts of the world. Moreover, a study published in the

journal *Science Advances* indicates that the Atlantic Meridional Overturning Circulation (AMOC) has weakened, potentially influencing the global climate system.



Electrification is advancing inevitably

In the EU, renewables' share of electricity rose from 25 per cent in 2012 to over 41 per cent in 2022, though country differences remain large. Sweden reached 66 per cent, Finland 48 per cent, while Belgium and Ireland were below 14 per cent.

Although energy efficiency has increased, the progress remains slower than needed to meet climate targets. Even oil-rich Norway expects electricity consumption to double over the next 25 years as part of its strategy to cut emissions.

The EU's Corporate Sustainability Due Diligence Directive obliges large companies to prepare transition plans supporting the 2050 climate-neutrality goal.

Making the transition easier

Accelerating the energy transition also requires new business models, legislative development, and a shift in public attitudes. Consumer energy communities,

for example, represent a promising way to promote new forms of energy. They enable consumers to use sustainably produced energy and ensure more reliable energy supply.

Research from the University of Vaasa shows that citizens face multiple barriers to joining energy communities – including policy uncertainty and technical challenges. Removing these barriers will be vital for inclusive participation in the energy transition.

University of Vaasa driving the transition towards a sustainable society

Sustainable business, energy, and society lie at the heart of the University of Vaasa's strategy. The university promotes innovation that creates value both for industry and for society as a whole. This means advancing clean energy, economic growth, industrial innovation, and sustainable consumption and production.

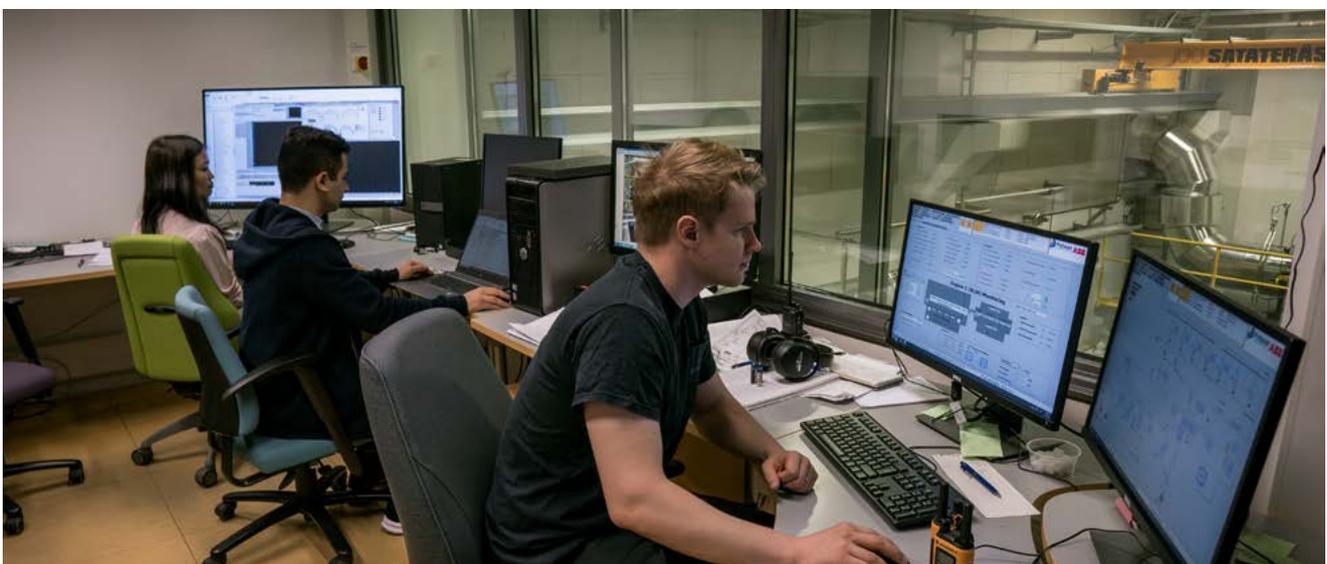
A concrete example of this commitment is the Efficient

Powertrain Solutions research group, which supports the end-to-end process of powertrain development from fuel to energy and emission management while its research focuses on combustion engines.

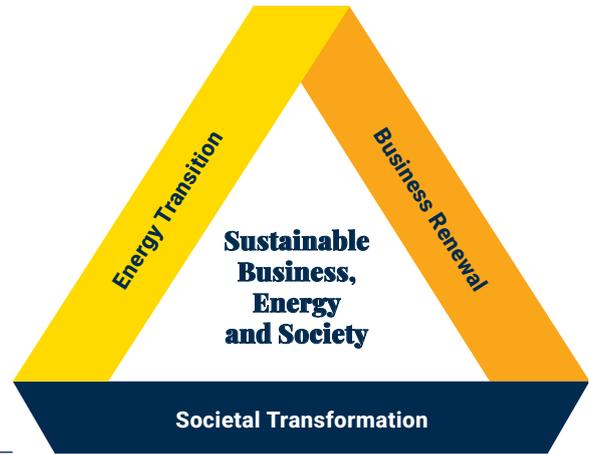
The Renewable Energy and Built Environment (REBE) group conducts interdisciplinary research across the entire energy cycle, from sources and storage to consumption, with a primary focus on low-emission and low-energy buildings, districts, and cities.

The energy transition – towards a more sustainable future:

- The energy transition is essential to mitigate climate change.
- Investments in renewable energy are growing rapidly but are still insufficient.
- While U.S. energy policy currently favours fossil fuels, Europe and Asia continue to expand clean energy use at pace.



Energising Sustainable Futures



The University of Vaasa educates experts in sustainable growth by combining deep understanding of energy transition, business transformation, and societal change.

The World Economic Forum has urged countries to invest in talent that accelerates clean energy innovation and deployment – not only to meet climate targets but also to strengthen economic competitiveness.

The energy transition demands multidisciplinary expertise. Technical competence remains essential but must be complemented by business innovation, policy understanding, and the ability to design scalable and user-centred solutions.

The University of Vaasa's close cooperation with the Nordic region's largest energy technology cluster is a unique asset. The interaction between research and industry brings together companies, scientists, and students to co-create practical, research-based solutions.

The university collaborates with companies, communities, and other research institutions through co-funded projects,

commissioned research, and joint infrastructures.

It also promotes societal impact through the CoDoc model, where doctoral candidates conduct research that directly supports company needs while maintaining high academic standards.

Companies and research partners can access the university's advanced energy laboratories, including:

- a fuel laboratory supporting future fuel research,
- an engine laboratory for testing combustion and emission control, and
- a geoenery laboratory focused on geothermal heat and thermal storage solutions.

Energy transition in education and research

The University of Vaasa offers a comprehensive portfolio of education and research in energy transition. Its degree programmes develop multidisciplinary

Research example: Zero-emission energy through collaboration

The University of Vaasa leads the **iHAPC** (Integrated Hydrogen-Argon Power Cycle) consortium, which aims to improve the efficiency of hydrogen combustion engines and enable fully emission-free power generation. The project tests a hydrogen-argon cycle that burns green hydrogen using electrolytic oxygen and argon as a medium. Partners include VTT Technical Research Centre of Finland, the University of Oulu, Wärtsilä, Parker Hannifin, Vahterus, Vaisala, and TotalEnergies. The project uses shared university laboratories and is primarily funded by Business Finland.

expertise essential for advancing the energy transition, sustainable business, and a sustainable society. For example, the **Smart Energy Transition master's programme** allows students to specialise in either electrical engineering or energy technology, combined with courses in digitalisation and business. The programme equips graduates to design flexible and intelligent energy systems for the future.

In electrical engineering, the focus lies on smart grids and digital integration of renewable production. Energy technology emphasises efficient, reliable, and environmentally sustainable energy production, including advanced combustion technologies that support the move towards low-emission solutions.

The multidisciplinary **Energy Transition module** integrates

technical, economic, environmental, and social perspectives, giving students the broad insight required to manage the ongoing transformation.

The University of Vaasa's distinctive strength lies in its ability to connect technology with business, governance, and society – precisely what is needed to lead the energy transition.

University of Vaasa research groups linked to the energy transition

Nine University of Vaasa research groups and two research platforms are directly involved in energy transition topics.

- **Cyber-Physical Systems** studies everything from smart devices to industrial automation and the interaction between the digital and physical worlds, including the use of satellite data in energy production.
- **Economics** explores policy measures and their effects, particularly in environmental economics, where externalities and innovation diffusion are key topics.
- **Efficient Powertrain Solutions** develops technologies essential for marine, industrial, and local power production.
- **Mathematical and Statistical Modelling** focuses on mathematics, econometrics, and statistics applied to energy and economic systems.
- **Networked Value Systems**

(NeVS) examines production management, digital manufacturing, and quality management. Its energy transition theme analyses how production and consumption evolve, addressing renewable technologies from local generation to industrial-scale solutions.

- **Public Policy and Governance** explores how public administration can adapt to complex societal challenges through collaborative and anticipatory governance. The group also includes a tenure track associate professor in energy law.
- **Renewable Energy and Built Environment (REBE)** studies low-carbon and energy-efficient building and urban design.
- **Smart Electric Systems (SES)** focuses on low-carbon, reliable, and flexible integrated power systems.
- **Strategic Business Development** investigates how companies can renew their

operations under the conditions of sustainable growth, digitalisation, and energy efficiency.

- **VEBIC research platform** – The Vaasa Energy Business Innovation Centre (VEBIC) is a multidisciplinary platform advancing the transition towards sustainable and efficient energy systems. It bridges research and industry, ensuring that innovations generate tangible societal benefits.
- **Preparedness and resilience (PREP) research platform** – The university's newest platform strengthens research on economic and societal resilience, comprehensive security, and preparedness, including areas such as energy security and the resilience of critical infrastructures.

Learn more about all research groups at the University of Vaasa:





**Research example:
Buildings as flexible
energy sources**

The **FlexiPower** project develops the “Building as a Battery” (Baab) concept, enabling heating and cooling systems to respond dynamically to grid needs. This enhances system flexibility and supports renewable integration.

Comprehensive business education and research

In addition to energy-related programmes, the University of Vaasa provides extensive education and research in business and economics. It offers master’s degrees for example in international business, accounting, finance, human resource management economics, business law, marketing, industrial management and strategic business development.

Nine research groups contribute directly to business renewal and sustainability:

- Auditing and Control in Accounting
- Finance and Financial Accounting
- Human Resource Management
- International Business and Marketing Strategies
- Cyber-Physical Systems
- Marketing and Consumption Research
- Mathematical and Statistical Modelling
- Networked Value Systems
- Strategic Business Development

These research groups also contribute their expertise to projects addressing the energy transition. Their work may focus, for example, on sustainable finance as an enabler of the transition, energy law, or sustainability and responsibility reporting. The Marketing and Consumption Research group, for instance, explores sustainable energy markets from both consumer and corporate perspectives.

The interdisciplinary platforms **Digital Economy** and **InnoLab** further support innovation and business renewal through digitalisation and social innovation research.

**Research example:
Genetically modified
plants for biofuel
production**

The international **ASAP** (Alliance for Socially-acceptable and Actionable Plants) project develops genetically modified plants designed for industrial biofuel production. The consortium, led by the University of Illinois, includes partners from the UK and Japan as well as the University of Vaasa, which studies the ethical and social acceptance aspects of synthetic biology in bioenergy. The Finnish subproject is funded by the Research Council of Finland.

Tools for managing societal change

The energy transition represents a profound societal transformation, influencing business, governance, and everyday life. Managing this requires foresight, interdisciplinary competence, and strong collaboration between sectors.

The University of Vaasa's degree programmes in administrative sciences provide students with skills to manage public services, regulation, and governance during complex change processes. Understanding both administrative and societal dynamics is essential for building resilient societies.

In the energy transition, it is particularly important to recognise perspectives from both citizens and decision-makers. For example, University of Vaasa researchers Petra Berg, Rummy Narayan, and Arto Rajala demonstrate how ideological standpoints significantly influence the types of energy solutions adopted at the municipal level.



Several research groups at the University of Vaasa have examined the energy transition from the viewpoints of both policymakers and citizens. For instance, the university's Communication Studies research group has studied climate change adaptation from the perspectives of citizens and journalists.

Preparedness and Resilience Research Platform

The university's newest platform strengthens research on economic and societal resilience, comprehensive security, and preparedness. In the context of the energy transition, the platform focuses on the resilience and energy security of energy systems and other critical infrastructures. The new research platform builds on the University of Vaasa's strengths in business, governance, communication, and technology.

Research groups focusing on societal change include:

- Human Resource Management
- Public Policy and Governance
- Cyber-Physical Systems
- Mathematical and Statistical Modelling
- Communication Studies
- Auditing and Control in Accounting
- Finance and Financial Accounting
- Business Law and Information
- Economics

Research example: Cybersecurity for future energy systems

REDISET (Resilient Digital Sustainable Energy Transition) aimed to develop descriptions of future energy systems and related threat scenarios. The project took a holistic approach to analysing and mitigating vulnerabilities in highly digitalised and interconnected energy systems, focusing on digital security and resilience. System simulations were used to develop and test resilience criteria, which were demonstrated in Vaasa.

The project was carried out by the University of Vaasa together with a Nordic research consortium.

The energy transition as a competitive advantage – Finland and Europe at the forefront

The energy transition is not only a climate action but also an economic, technological, and societal opportunity. It generates new jobs and growth, strengthens energy security, and offers Finland and the whole of Europe a chance to become a frontrunner in energy technology.



1. Investing in competence as the foundation of competitiveness

The energy transition requires diverse expertise – technical, commercial, financial, societal, and human. Experts must understand not only technologies but also their implications for people, markets, and governance, as well as how to make investments that enable the transition to happen.

The University of Vaasa plays a significant role by educating energy professionals and collaborating closely with industry to meet evolving RDI needs. This collaboration is further strengthened through the Energy Transition Valley initiative, which enhances regional research, development and innovation by providing new research infrastructure, joint

business-driven programmes, and extensive doctoral education.

The Finnish government's recent decision to allocate EUR 40 million via Business Finland for energy transition RDI is an important start, but long-term funding is needed to support skills development, research commercialisation, and regional competence clusters.

2. Consistent policies – direction and stability

The energy transition cannot advance without clear, predictable policy. Governments must provide a stable long-term framework for investments, infrastructure development, and social acceptance. Developing electricity transmission connections and ensuring their resilience is critical to enable new forms of generation – such



as decentralised renewable energy – to be efficiently integrated into the national system.

Studies show that markets develop slowly when only producers and consumers act as drivers; public organisations and civic actors are often needed to accelerate adoption.

3. Agile regulation and permitting to enable innovation

New business models in the energy transition require regulatory environments that are flexible, transparent, and digitally supported. At the same time, it is important to safeguard citizens' democratic participation, which is essential for the social acceptance of change. This does not mean neglecting safety or the environment but

rather implementing smart regulation that recognises and manages risks without stifling development.

4. A unified yet flexible Europe

The energy transition is a shared European project. The EU must set common goals but allow national flexibility in implementation. Eliminating contradictory or overlapping legislation is key to scaling innovations across the Union.

Finland can position itself as a leader in smart energy technologies within Europe – especially by capitalising on the strong expertise concentrated in the Vaasa energy technology cluster.

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