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Whitepaper

SECTOR COUPLING

The Key to a Successful Energy Transition in Switzerland

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Executive Summary

Switzerland is at a crossroads in its energy transition. The challenge ahead is to balance three interdependent priorities: reducing emissions, ensuring a secure energy supply, and keeping costs affordable. These objectives must be pursued together and recognized as a national target with foresight and coordination to safeguard prosperity while protecting the environment for future generations.

For decades, our energy system functioned like a single large wheel: top-down, centralized, stable, and relatively predictable in cost. Energy sources and supply chains were not questioned as long as their availability were guaranteed. That era is ending. The future will be powered by thousands of smaller decentralized producers, from solar, wind, heat producers to storage systems, all of which must work in concert. Our energy system is like a Tinguely machine: every gear, large and small, must align. If they fail to align, the system will become inefficient and costly. If they are well coordinated, Switzerland will build a resilient, sustainable, and innovative energy economy.

In the near future, electricity and cooling demand will greatly increase in transport, data centers, heating, and cooling. A cornerstone for such a transition is Sector Coupling, therefore the intelligent integration of electricity with heating, cooling, transport, and industrial processes. Through electrification and technologies such as power-to-heat, power-to-hydrogen, and power-to-mobility, we can increase the overall efficiency of the energy system, enhance flexibility in balancing demand and supply, and accelerate the decarbonization of the economy. Thus, Switzerland could save billions in unnecessary grid extensions, stabilize prices, and reduce dependence on fossil fuels from abroad; a responsibility we all share.

Realizing this vision requires decisive action in at least five areas:

- **Digitalization:** smart grids, AI, robust ICT to manage distributed supply and demand.
- **Regulation, research & innovation:** frameworks that reduce administrative hurdles, enable Local Energy Associations and dynamic tariffs while fostering innovation
- **Financing:** investment strategies that move beyond short-term profit toward long-term, sustainable value creation, enabled by the cooperation between public and private sectors.
- **Collaboration:** recognition that Switzerland is not an energy island; success depends on integration with the wider European energy system and on experts who take responsibility and actively seek cooperation with strong partners.
- **Holistic planning:** connect well established and new technologies intelligently and at the earliest possible stage of a project, with all stakeholders involved and accountable.

The transition will carry costs — but inaction will cost far more. Technologies are ready and already being deployed. They must now be scaled nationwide. Scaling these solutions will deliver affordable, stable energy, create skilled jobs, and reinforce Switzerland's competitiveness and energy security. The opportunity is clear: to transform the greatest challenge of our generation into a sustainable, economic, and human advantage. The time to act is now. Through innovation, investment, and collaboration, we can ensure a secure and regenerative energy future for Switzerland.

Energetic regards

Daniel A. Oechslin & Frank Schürch

SECTOR COUPLING

The Key to a Successful Energy Transition in Switzerland

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Introduction

This whitepaper emerged in January 2025 from the network of the energie-cluster.ch, Switzerland, in close cooperation with oe.energy. Its purpose is straightforward: to make the energy transition visible and understandable. Not only for experts, but also for citizens, small businesses, academics, politicians, and authorities — all have a role to play.

The question at the heart of this paper is: “How can I contribute?” The answer spans every level of society, from individuals and SMEs to cities, cantons, authorities and politicians, universities and research institutions, and of course energy companies. The transition is not the responsibility of a few. It is a national project in which every actor has influence and can make a difference.

Our aim is to provide inspiration, information, and reference in equal measure. We want to show that a hybrid energy landscape where electricity, heating, mobility, and digitalization work together, is not just a vision, but already a reality in Switzerland. Projects presented here demonstrate how coal, gas, and oil can be avoided by 2040; this is well ahead of the current national strategy and made possible by smarter integration and faster adoption of proven technologies.

In addition, we provide cross-sectoral analyses of energy availability and prices, the role of digitalization and artificial intelligence, and the ICT backbone — highlighting both strengths and weaknesses as well as opportunities and risks.

Our intent is also to build a movement: a network of innovators, policymakers, companies, and citizens committed to accelerating Switzerland’s energy transition. With cooperation and determination, Switzerland can transform its energy system into a regenerative, resilient, and sustainable foundation for future generations.

The teams around the report wish you an interesting read and are open to exchange ideas and projects with interested parties of all kinds. We are convinced that we have created an independent, novel approach for understanding the central importance of coupling our energies.
Join us in 2026!

Kind regards, your sector coupling team!

PARTICIPANTS OF OUR INITIATIVE AND THEIR RESPECTIVE PROJECTS (in alphabetic order):

1. Bank Julius Baer: Energy Market Update – Swiss private banking group, providing financial analysis and market insights, including developments in global energy markets.
2. B-Solartec: Ice Storage System – Provider of innovative solar and thermal storage technologies.
3. Canton of Bern: Concept for Energy Infrastructure Expansion (KAEN) – Cantonal authority responsible for energy strategy and infrastructure planning.
4. City of Thun: Climate Strategy – Local authority engaged in regional energy development.
5. EBP Schweiz AG: Installation of public EV charging infrastructure; Campus Münsterlingen – Engineering and consulting company for energy, environment, and mobility solutions.
6. Everllence: Esbjerg Mega-Heat Pumps – International consultancy specializing in large-scale energy transition projects.
7. Verband der Schweizerischen Gasindustrie VSG (GazEnergie): GreenGas (with Planair) - Association of the Swiss Gas Industry.
8. Green Energy Venture: Plusenergiestadt Burgholz – Developer of renewable energy and positive-energy community projects.
9. HEIG-VD (Vaud): Impact of Heat Pump Integration on Power Distribution Grids – University of Applied Sciences Western Switzerland, applied research in energy and systems engineering.
10. Hoval: Lake Energy Project Steinach SG – Manufacturer and technology provider for heating, cooling, and energy systems.
11. HSLU (Lucerne): Decarbonization of Pilatus Kulm – Lucerne University of Applied Sciences and Arts, applied research on energy and building systems.
12. Huawei: The Role of ICT in the Digitalization of the Energy Sector – Global technology company providing smart PV inverters, energy storage solutions, and digital energy management systems.
13. Planair: Energy Renovation of Victorinox Industrial Site; GreenGas (with VSG) – Engineering consultancy for sustainable energy and efficiency solutions.
14. Romande Energie: Microgrid Les Cèdres – Regional Swiss utility focused on renewable energy generation and supply.
15. Société des Forces Électriques de la Goule: The Swiss Energypark – Regional electricity utility showcasing innovative energy concepts.
16. Swiss Renewable Solutions: Sector Coupling at Dyno AG – Developer of integrated renewable energy projects and sector coupling solutions.
17. Tend: Systematic Building Renovation – Specialist in sustainable building renovations and CO_2 reduction for buildings and real estate portfolios.

Energy Market Update

'DUNKELFLAUTE', 'HELLBRISE', AND SECTOR COUPLING

Norbert Rücker
Head of Economics & Next Generation Research, Bank Julius Baer
President, energie-cluster.ch

How quickly times change. Not long ago, Switzerland feared for its electricity supply when Russia turned off the gas taps to Europe and France sent more nuclear reactors than usual into maintenance. Today, the discussion is different. Sunny weather regularly causes a surplus of electricity at lunchtime and especially on weekends. The rapid expansion of solar power and the speed of the energy transition are testing the system. In recent years, the economic stop-and-go following the pandemic, geopolitical events in Europe and the accelerated energy transition have triggered unprecedented dynamics on energy markets. Even though much of the dust has now settled, it remains a challenge to disentangle the different factors at play. The crisis has ultimately sped up the transition.

A look at electricity prices helps maintain perspective. Comparing wholesale prices in Switzerland with those of neighboring countries reveals more clearly than almost any other indicator what drives the market and in which direction it is heading. First observation: Switzerland follows Europe. Even though the discussions sometimes give the impression that we live on an electricity island, the reality is quite different. Switzerland is firmly integrated into a tightly interconnected European

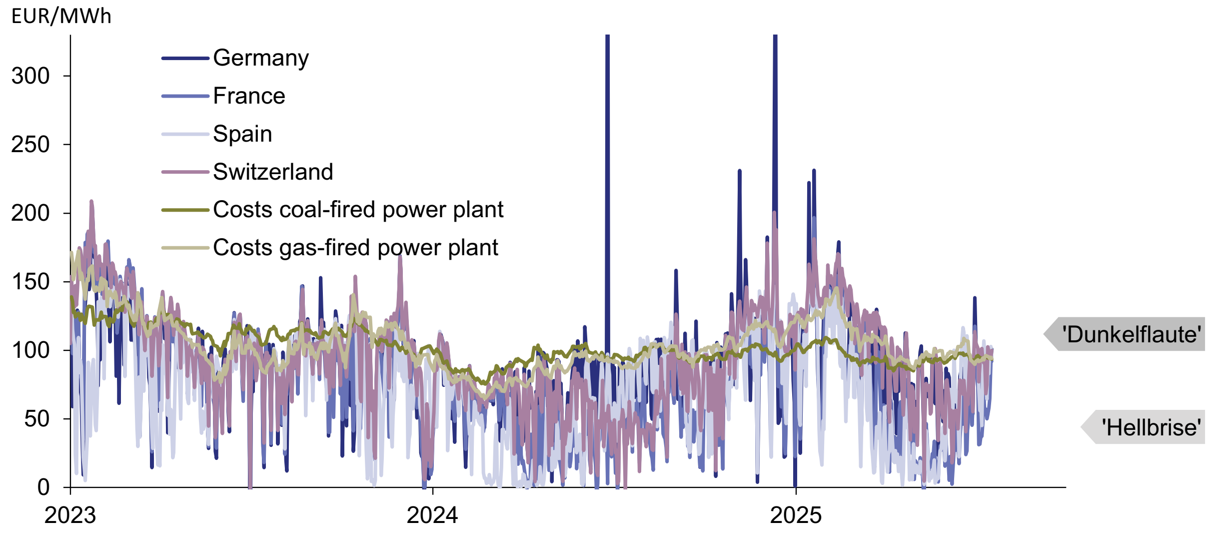


Figure 1. Wholesale electricity prices in Europe. *Source: Bloomberg Finance L.P., Julius Baer (MWh: megawatt hours).*

electricity market. In hardly any other comparable country – with the exception of Denmark – do traded electricity volumes and cross-border transmission capacities match total demand as closely. As a result, electricity prices reflect market developments in Europe more than those in Switzerland. If Germany is enjoying plenty of spring sunshine or a storm is sweeping across northern Europe, this has at least as much of an impact on our prices as heavy rainfall in the Alps.

Second observation: the costs of gas-fired power plants cap electricity prices, in Europe and in Switzerland alike. Gas-fired power plants are usually more expensive than other power plants and supply electricity when these are insufficient. This so-called merit order has become a more familiar concept since the energy crisis. While this effect sometimes means higher power prices, it is essential for Europe's supply security. Northwestern Europe has more than 40 gigawatts of installed capacity in gas-fired power plants, which helped compensate for outages of French nuclear reactors. These capacities are also critical for covering winter wind lulls in Northern Europe. Their use is sporadic, which means CO_2 emissions are much lower than from other sources. Switzerland relies on its own reservoirs in winter, but Europe's gas-fired power plants remain our ultimate insurance policy.

The risk of power shortages has long been averted – and would only have materialized had Europe's gas storages run empty following reduced Russian deliveries. As we now know, the opposite happened. Europe's storages were filled to the brim from late 2022 through last year. Two mild winters helped, but were not decisive. Economists were less surprised by this outcome than the public. The sharp rise in gas prices attracted imports, curbed demand, and ensured full storages. Such dynamics are well known in commodity markets – especially in globalized markets like gas and oil, which are highly resilient to shocks. China's ramp-up of coal production offset the loss of Russian gas, enabling Europe to import liquefied natural gas originally destined for Asia. Temporarily high prices and economic costs were the flipside of this supply security. Unfortunately, recurring unfounded supply fears and clumsy regulation kept willingness to pay unnecessarily high and drove up gas and power prices – as in late 2024. Less noticed was that China, during the crisis, experienced the opposite: fixed prices and regulatory constraints left the market too rigid and inflexible, leading to widespread power outages. China learned its lesson and is now establishing an electricity market modeled on Europe's. A new era has begun in the gas market. Numerous export terminals are coming online, for example in Canada, while the energy transition curbs import demand in countries such as China. These seemingly distant trends are just as relevant to Switzerland's security of supply as Alpine solar power plants – and they push down the gas cap on electricity prices.

Third observation: prices fluctuate strongly. The term 'Dunkelflaute' ('dark lull') is no longer reserved for experts. It describes periods when solar and wind farms generate too little electricity, making gas-fired power plants and their costs the price-setting factor. A closer look, however, shows that 'Hellbrisen' ('bright breezes') occur more frequently. These are the opposite phases, when solar and wind power are in oversupply.

> **OUR DISCUSSION OF A WINTER ELECTRICITY GAP REFLECTS POLITICAL NEEDS MORE THAN ECONOMIC REALITIES.**

Because renewables have no operating costs, are often tied to fixed remuneration systems, and because coal and nuclear plants are only partially flexible, prices during 'Hellbrisen' often drop to zero or even negative. This phenomenon is more pronounced than the graph suggests. Hours with wholesale prices at or below zero are steadily increasing. In May and June of this year, Germany saw just ten days with positive midday electricity prices. 'Hellbrisen' occur regularly in spring and summer, as well as in winter – since Europe's renewable output is actually highest in winter, not summer. With the continued build-out of offshore wind and transmission networks, this positive winter seasonality will persist for the foreseeable future. Europe does not face a winter electricity gap. The existing – and still expanding – capacities of wind, gas, and batteries in Europe are so substantial that they largely overshadow Switzerland's seasonal trading imbalance. Our discussion of a winter electricity gap reflects political needs more than economic realities.

The market is based on countless daily decisions made by households and businesses. It is these very decisions that drive the energy transition and gradually but steadily reshape the system. Costs – affordability – are only one factor. Equally important are choice, responsibility, motivation, and knowledge to make objective, rational decisions. When buying a car, nearly all these conditions are met, which is why electric vehicle adoption is rising relatively quickly. Housing is different. Rental structures and condominium ownership complicate decision-making. Landlords invest in heating and pass costs on to tenants. Condominium owners often struggle to reach joint decisions. This asymmetry in responsibility and motivation explains why heat pumps or home charging stations spread more slowly, even though their long-term economics are convincing. Understanding these fundamentals deserves more attention, as the energy transition brings increasing decentralization. The number of actors is steadily rising – from rooftop solar producers large and small to households with heat pumps and electric cars. More and more energy-relevant decisions are being made. For this new energy world to unfold, the framework must evolve. Two areas stand out.

The system needs flexibility. The sharp intraday, daily, and weekly price swings speak clearly. To integrate all these countless participants and make them share responsibility for supply security, there is no better tool than price. Solar power flows into battery storage systems at home or into electric cars in company car parks at midday when it is cheap to buy. Industrial heat pumps or residential boilers pause on a windless winter evening when electricity is expensive. Price steers supply security. This has long been understood in Europe, and innovation-driven utilities already persuade customers with such solutions – thanks to market liberalization.

The system also needs a reliable grid. Surpluses and deficits are balanced by the network. Engineers are ahead of economists here. While grid expansion and modernization advance, the debate about financial incentives remains in its infancy. Whether this expansion is cost-efficient is rarely questioned. In a system where more and more actors both consume and feed-in electricity, today's grid tariffs are ill-suited to fairly distribute costs. The discussion is gaining momentum and often centers on a new, concrete model: grid fees based on connection size rather than consumption, on kilowatts rather than kilowatt-hours. In other words, one system for all, similar to what most industrial and commercial large consumers already face. Such a design creates incentives for everyone at the lower grid levels to contribute to stable supply and low overall costs. The midday solar surplus from a rooftop should not translate into higher bills for neighbors due to rising grid costs. A system designed for individual peak loads is more expensive than necessary for the general public. Local grid operators know their supply conditions best. Allowing them to pass on this knowledge through connection-based tariffs – differentiated by time of day and by consumption versus feed-in – would mark a big step toward a fair, affordable, and secure energy transition. Dynamic electricity prices and dynamic grid tariffs complement each other, delivering price signals that reflect the situation in both supra-regional power markets and local networks.

These examples show that so-called sector coupling – linking electricity with heat and mobility – occurs when the market is allowed to play its role. The strong price fluctuations make many investments in sector coupling solutions attractive. As a result, flexibility and security increase. The fertile ground for such investments is a system that passes on price signals to all – for both electricity and the grid. Even though frameworks in Switzerland and Europe still too often discriminate, there is no shortage of innovation, entrepreneurial spirit, and pioneers already tackling these challenges of the energy transition head-on today. ■

The role of ICT in the digitalization of the energy sector

Christian Kuster
CTO Huawei Enterprise Switzerland

DESCRIPTION

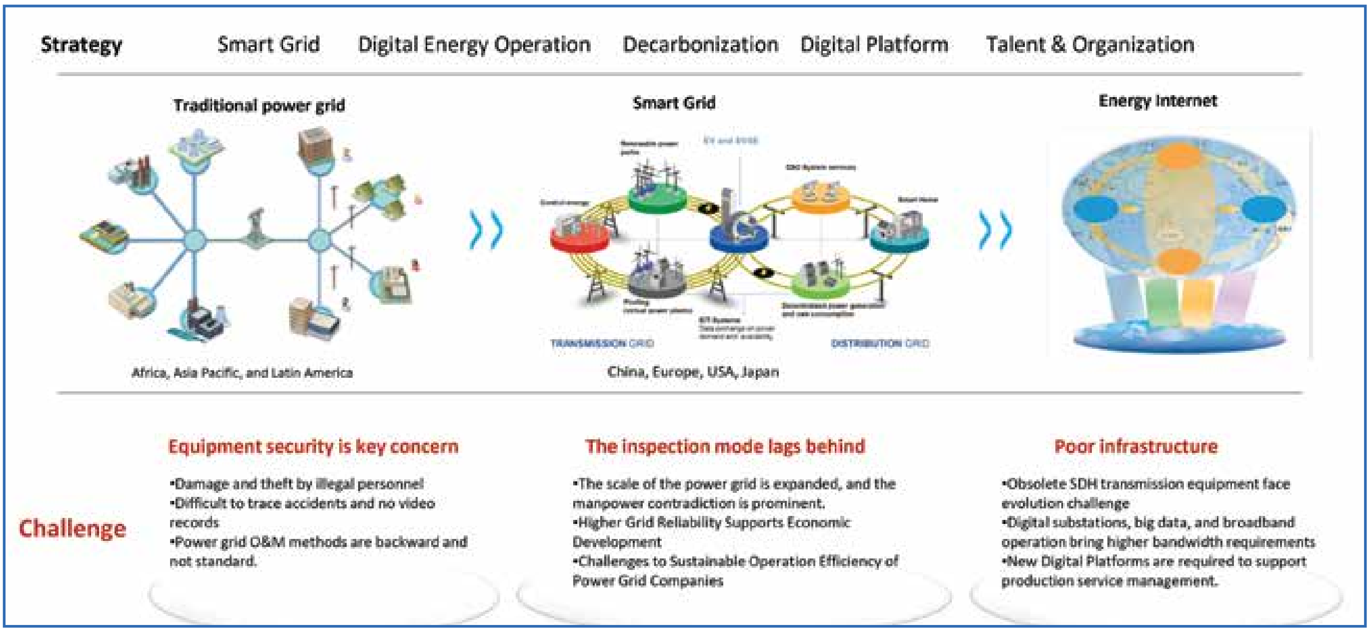
The development trend of power grids is moving from traditional power grids to smart grids and further moving towards regional and even global energy Internet in the future. Currently, many developed countries are in the smart grid stage, and more developing countries are in the transition stage from traditional grids to smart grids.

CHALLENGES

1. Safety production, especially equipment security, is a continuous core concern, and faces problems such as illegal damage, difficult to detect and locate faults in a timely manner.
2. Backward routine O&M mode: The increasing workload of devices and inspection and the high production security requirements are required. The backward mode that relies solely on manual inspection is becoming more and more difficult to support.
3. Old ICT infrastructures, such as transmission equipment, have gradually become bottlenecks for new services. In addition, there is a great need for digital and intelligent infrastructure platforms in many power grid companies.

GOALS

Support is required for robust and smart grids through digital innovation and transformation. We



Equipment security is key concern

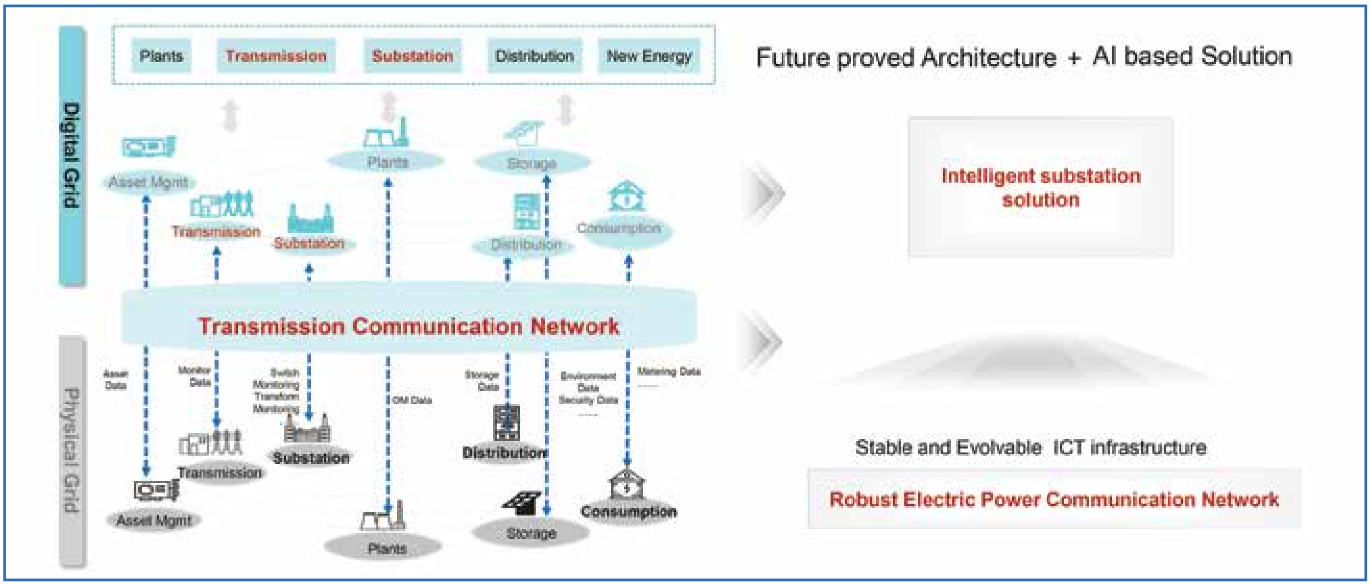
- Damage and theft by illegal personnel
- Difficult to trace accidents and no video records
- Power grid O&M methods are backward and not standard.

The inspection mode lags behind

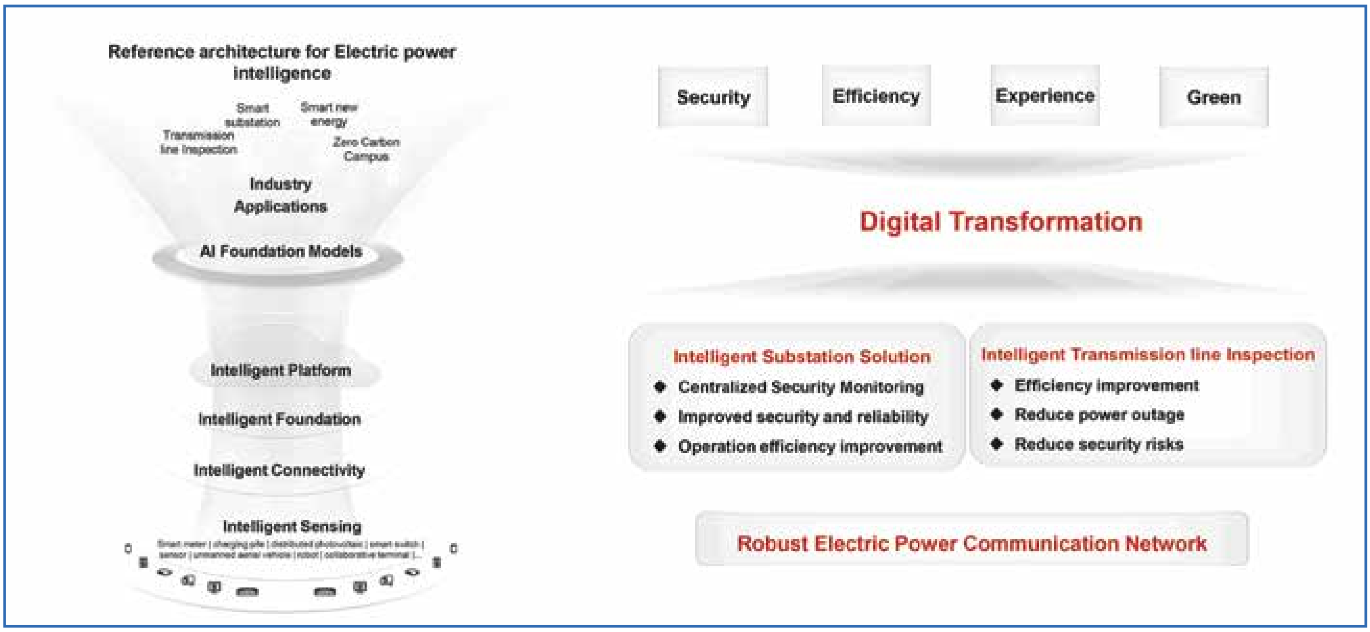
- The scale of the power grid is expanded, and the manpower contradiction is prominent.
- Higher Grid Reliability Supports Economic Development
- Challenges to Sustainable Operation Efficiency of Power Grid Companies

Poor infrastructure

- Obsolete SDH transmission equipment face evolution challenge
- Digital substations, big data, and broadband operation bring higher bandwidth requirements
- New Digital Platforms are required to support production service management.

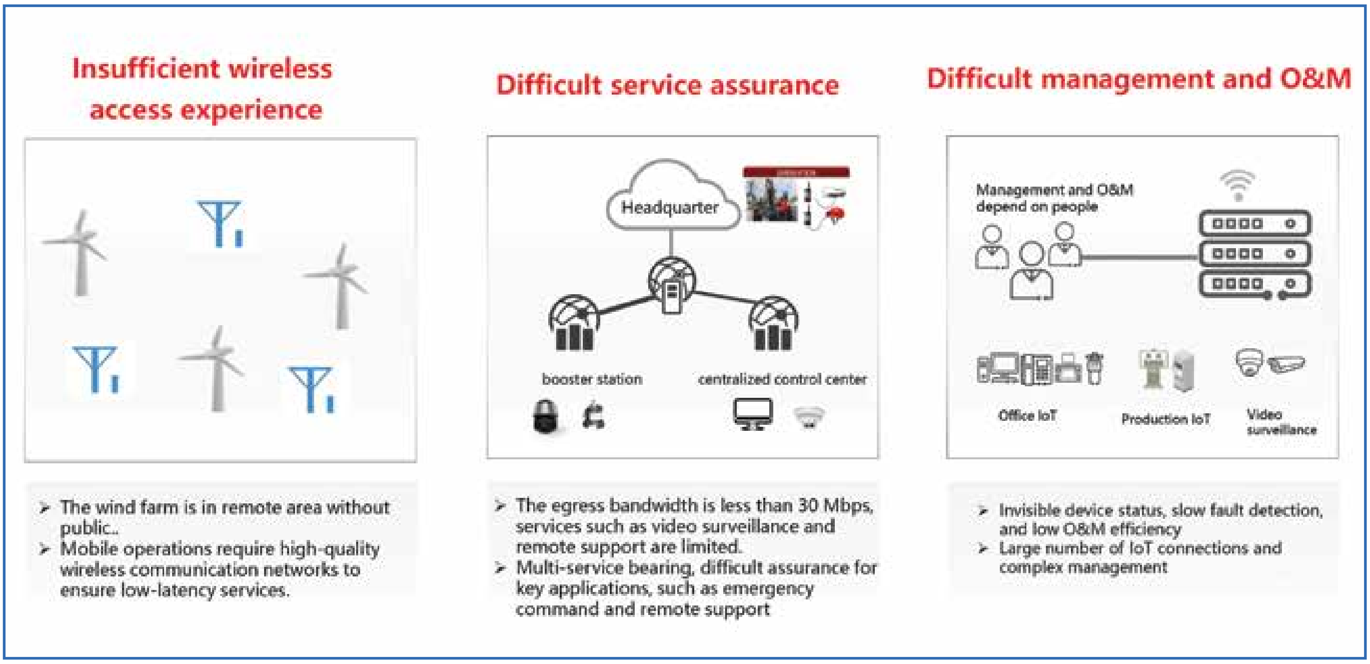


can look at the mapping between thse physical and digital worlds. The primary and secondary equipment included in the specialty of generation, transmission, transformation and distribution constitute the physical world. Through data sensing, collection, and backbone communication transmission, the physical world is projected to the digital world (Digital Twin), further building intelligent solutions in the digital world. Based on the future-oriented architecture and AI solutions, digital solutions such as e.g. the smart substation solution and smart transmission line inspection can be deployed. In addition, reliable and evolvable ICT infrastructures, such as power transmission and transformation communications networks, need to get more attention. All energy sectors need to provide a reliable power communication network as a solid digital foundation, which finally helps the ecosystem actors to continuously improve security, efficiency, greenness and user experience.



PROJECT EXAMPLE OF THE DIGITALIZATION IN THE WIND FARM SECTOR

CHALLENGES



Insufficient wireless access experience

- The wind farm is in remote area without public..
- Mobile operations require high-quality wireless communication networks to ensure low-latency services.

Difficult service assurance

- The egress bandwidth is less than 30 Mbps, services such as video surveillance and remote support are limited.
- Multi-service bearing, difficult assurance for key applications, such as emergency command and remote support

Difficult management and O&M

- Invisible device status, slow fault detection, and low O&M efficiency
- Large number of IoT connections and complex management

CONCLUSION

To address the above-mentioned challenges, a robust communication network is the key infrastructure.

When analyzing the situation in Switzerland, the availability of an existing communication infrastructure like 5G and fiber coverage as an enabling factor to establish the required communication networks is on a very good level compared most European countries as well as globally.

The combination of Switzerland's advanced public 5G infrastructure and a supportive regulatory environment regarding private 5G deployments makes it a fertile ground for the required key infrastructure.

GOAL & IMPACT

By successful digitalization of a specific sector (in this case energy production through wind power), it becomes a potential candidate to be coupled to other sectors through the "energy internet".

TARGET:
THE ENERGY INTERNET

The Energy Internet can be described as an advanced, intelligent and decentralized system that integrates all energy sectors. The goal is to couple traditional and renewable energy, energy storage, smart grids and digital technologies to achieve an efficient, flexible and sustainable energy management.

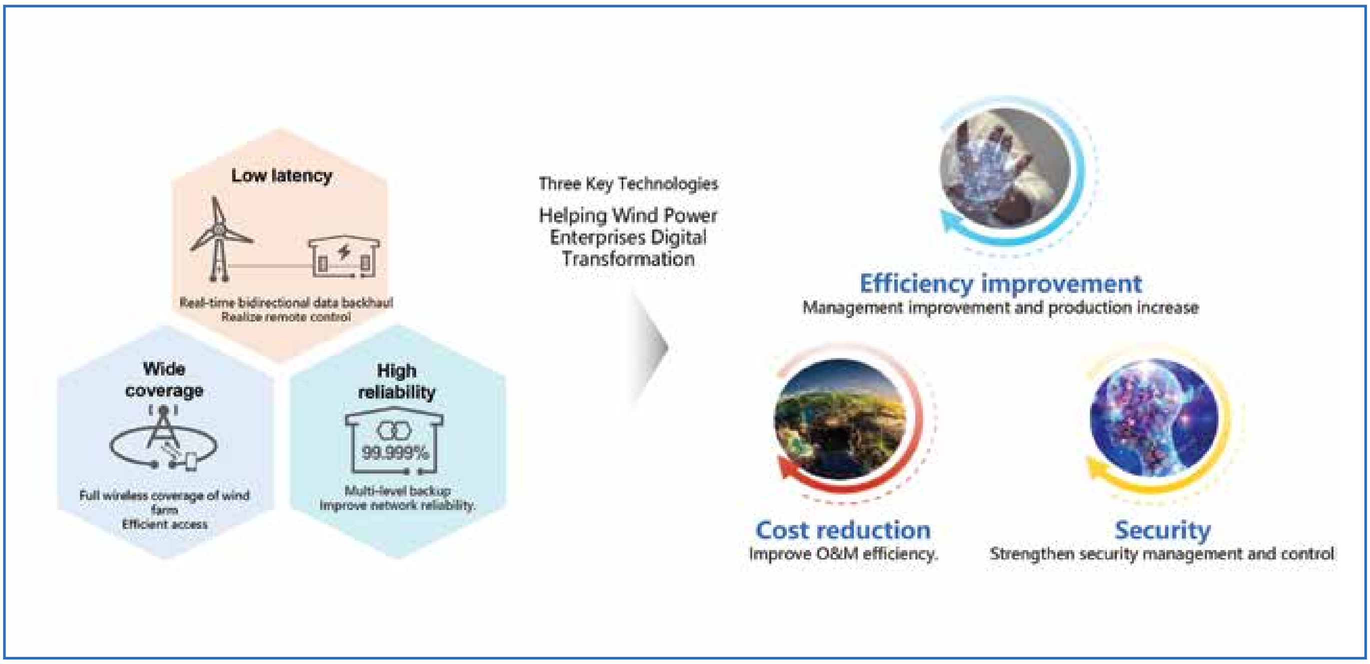
It also could be called the next-generation energy infrastructure, which is inspired and based on the principles of the Internet:

- Decentralization
- Interoperability
- Real-time data exchange

PRINCIPLES OF THE ENERGY INTERNET

1. Decentralized Energy Generation and Storage

a. Uses distributed energy resources like solar panels, wind turbines and microgrids instead solely rely on centralized power plants



b. Promotes prosumers (consumers which also produce and store energy)

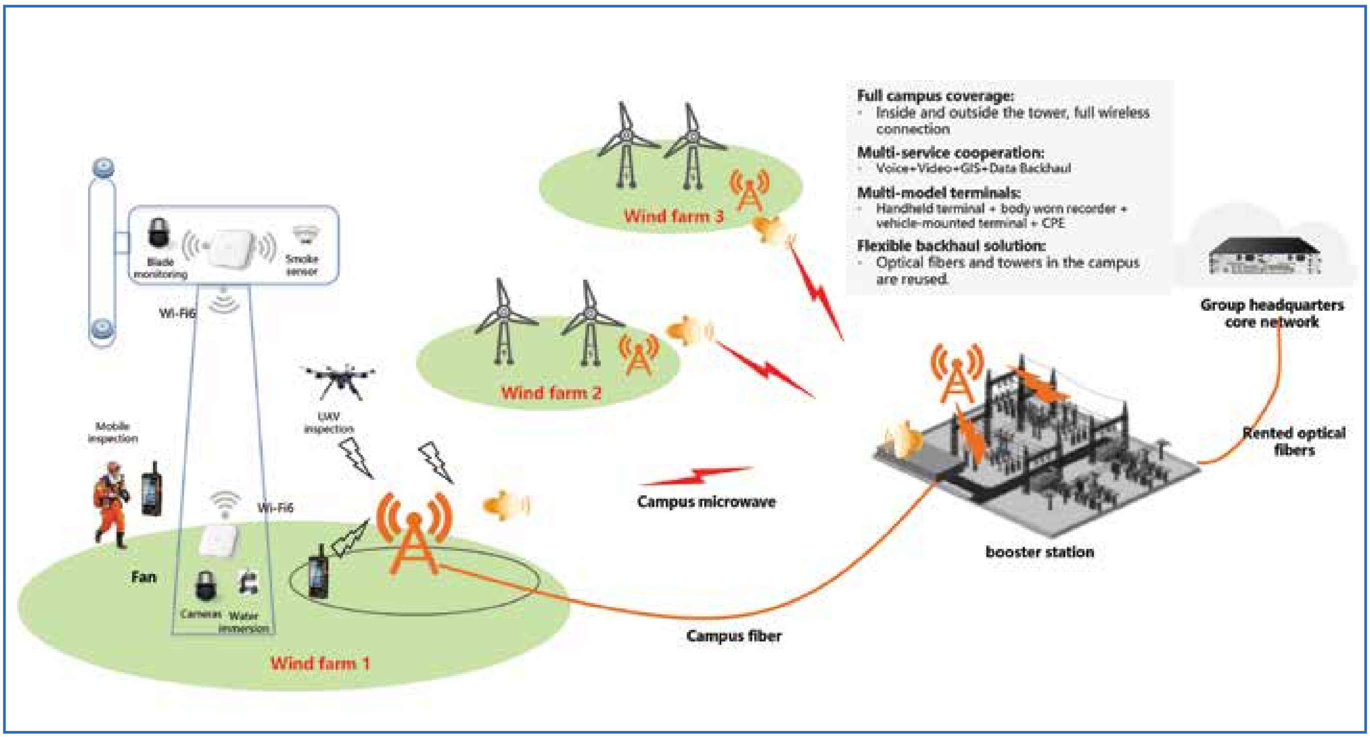
2. Digitalization & IoT Integration

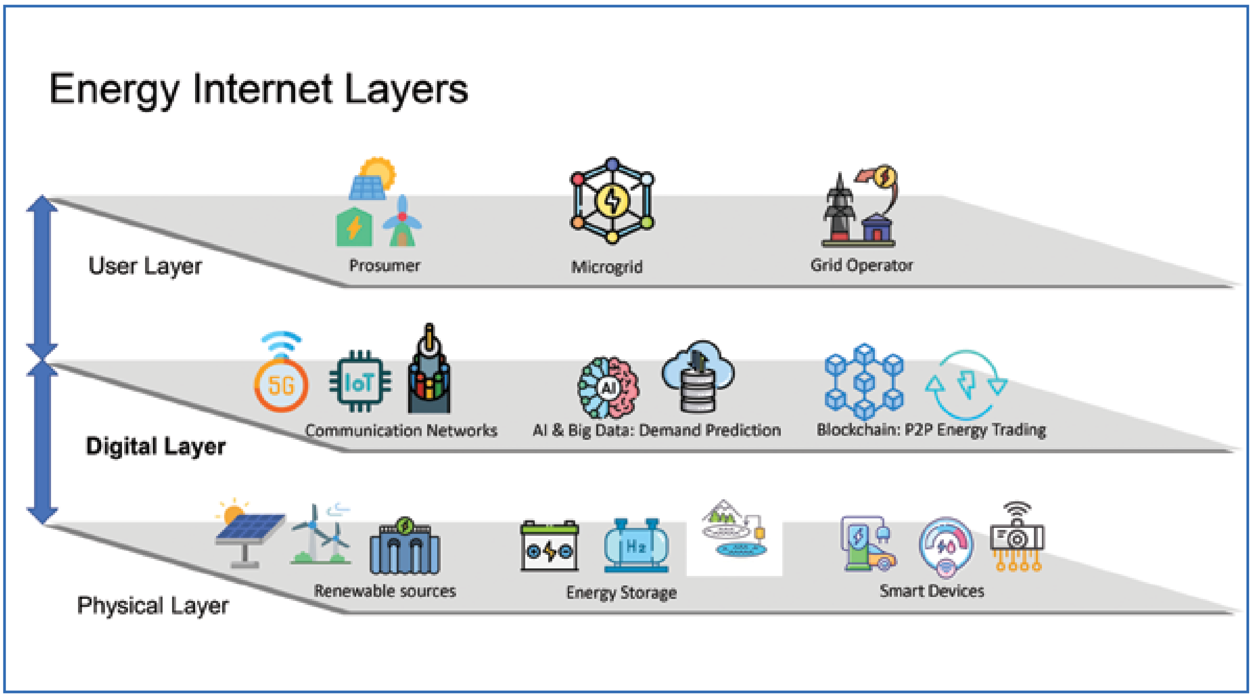
a. Smart meters, sensors and AI optimized energy flows in real time

b. Blockchain technology to enable peer-to-peer energy trading

3. Renewable Energy Dominance

a. High penetration of solar, wind, hydro and other clean energy sources





b. Energy storage (batteries, hydrogen) balances supply and demand

4. Smart Grid & Demand Response

a. Grids automatically adjust to fluctuations in supply and demand

b. Consumers can adjust usage based on price signals (dynamic pricing)

c. Combines electricity, heating, cooling and gas networks for higher efficiency

d. Electric vehicles (EVs) act as mobile energy storage units (V2G – Vehicle-to-Grid)

BENEFITS OF THE ENERGY INTERNET

- Higher efficiency – Reduces energy waste through smart management
- Lower Carbon Emissions – Accelerates the transition to renewables
- Energy Resilience – Less vulnerable to outages due to decentralization
- Consumer Empowerment – Users can trade energy and optimize costs

CHALLENGES

- High initial investment in infrastructure
- Cybersecurity risks due to increased connectivity
- Regulatory and policy barriers

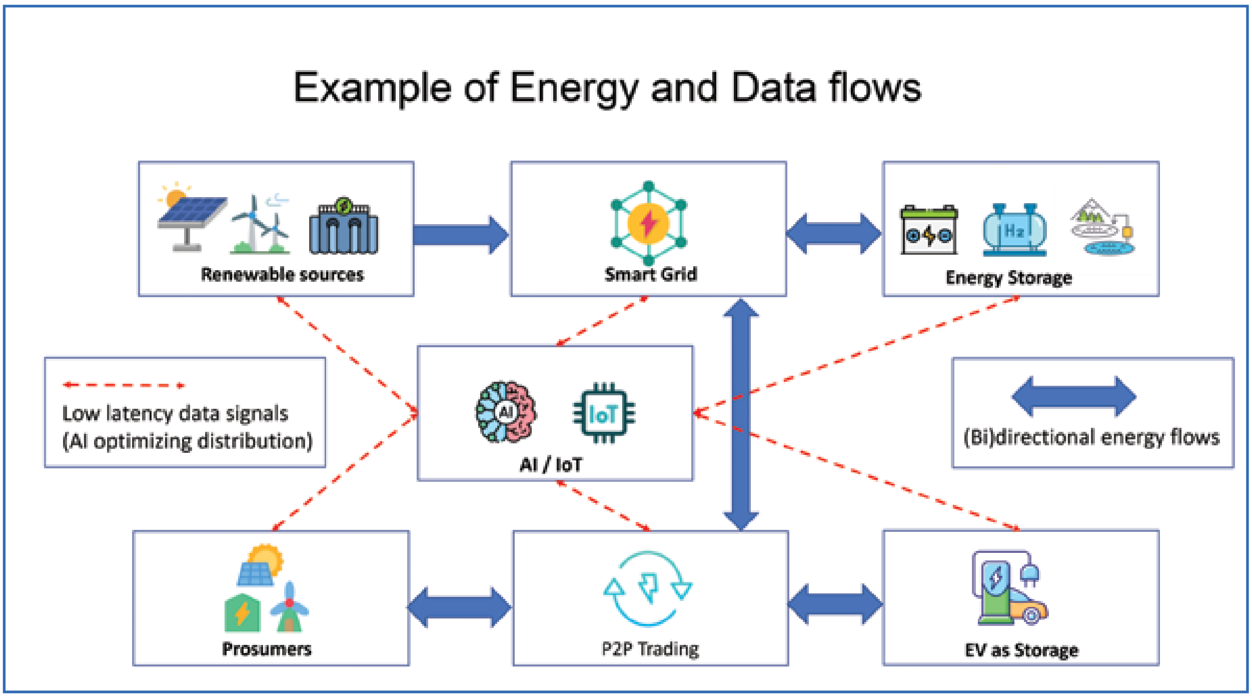
EXAMPLES & APPLICATIONS

- Microgrids in communities and industrial parks
- Virtual Power Plants (VPPs) that aggregate distributed resources
- P2P Energy Trading Platforms

The Energy Internet is a cornerstone in the future smart city and carbon-neutral economy, aligning with sustainability goals like the Paris Agreement.

SUMMARY

Energy Internet Connectivity across the Ecosystem as the Energy Internet gains momentum. The ecosystem of transactions will shift from the current Business-to-Consumer (B2C) model to include and then be dominated by Consum-



er-to-Business (C2B) and even Consumer-to-Consumer (C2C) models.

As more IoT & AI enabled services become commercially available, consumers will find multiple options tailored to suit individual cases. In practice, “Energy plus Internet” will be achieved by ICT-enabled information exchanges and distribution platforms that allow power resources to be accessed and managed through the universe of mobile, PC, and Internet connected appliance-based applications.

The state of the Energy Internet and Sector Coupling in Switzerland is characterized by advanced technological prowess, strong policy ambition, and significant potential, yet it faces challenges in scaling and regulatory harmonization.

Switzerland, with its unique energy system (strong hydropower base, nuclear phase-out, and high import/export dynamics), is therefore a fascinating case study, which can serve as a challenging and interesting pilot implementation and can take on a pioneer role in the transformation to the energy internet. ■

Scope level: Building

At the building level, decarbonization efforts target the systems that directly affect a site’s energy performance: heating and cooling infrastructure, ventilation, building envelope, and the integration of renewable energy sources. Buildings are both producers and consumers of energy—and often hold untapped potential for efficiency gains, heat recovery, or on-site generation. Whether newly built or undergoing renovation, a building’s role in energy transition depends on detailed system knowledge, long-term planning, and the ability to connect technical measures with operational needs. The following examples illustrate different approaches to decarbonization at the building level.

Project Example: Decarbonization of Pilatus Kulm

PROJECT DESCRIPTION

This project explores options for a sustainable, low-emissions thermal energy supply for the properties located at Pilatus Kulm, specifically Hotel Kulm, the Panorama Gallery, and Hotel Bellevue. The current system partly depends on fossil fuels transported to the mountaintop, which is logistically challenging and environmentally unsustainable. The new concept aims to replace these with integrated renewable solutions that maximize energy autonomy while meeting technical and ecological requirements. Multiple supply concepts were evaluated, including air-source heat pumps, PCM-based seasonal storage, and sorption systems. While several of these options were technically feasible, a value-benefit analysis shortlisted two main approaches: a geothermal probe field with solar regeneration and a combined PV-hydrogen system. Planning also considers the potential renovation or reconstruction of Hotel Bellevue, which could influence the choice and configuration of technologies. Beyond its local impact, the project offers a model for decarbonizing alpine hospitality infrastructure in Switzerland and similar off-grid locations.

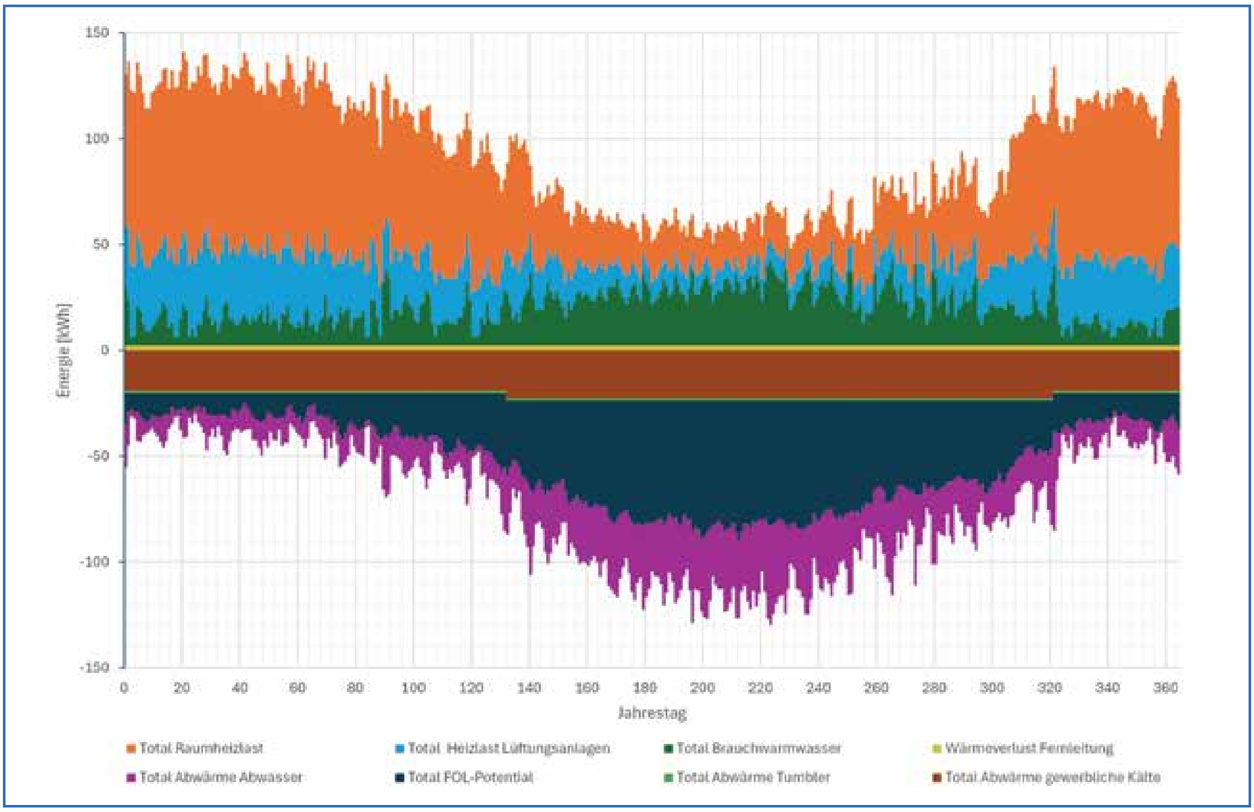


Diagram 1: Annual duration curve Pilatus Kulm | The positive Y-axis shows the thermal demand, while the negative area represents the thermal waste heat potential.

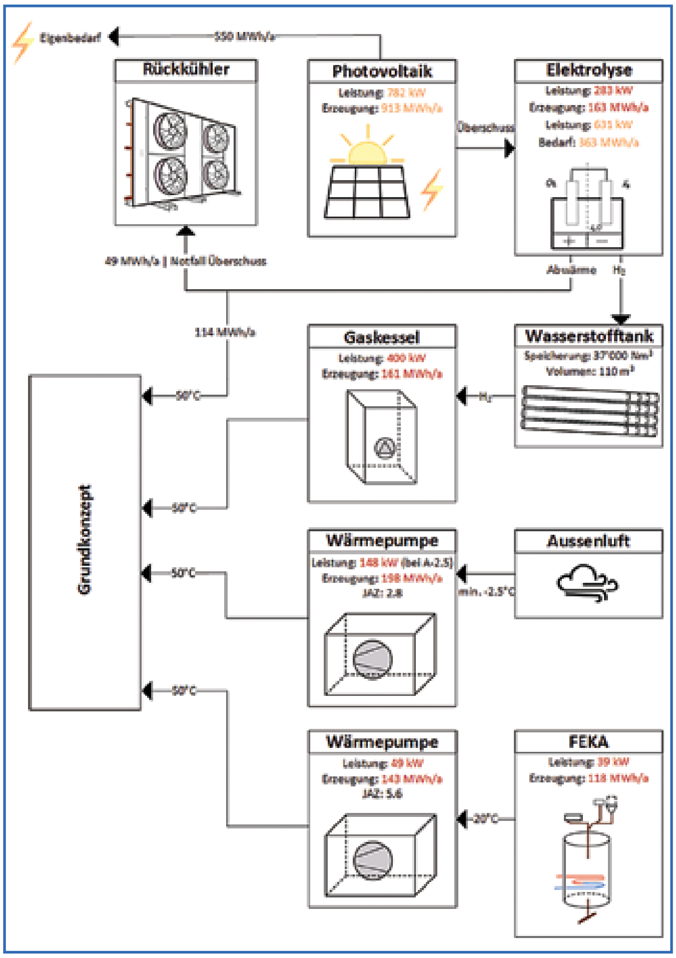
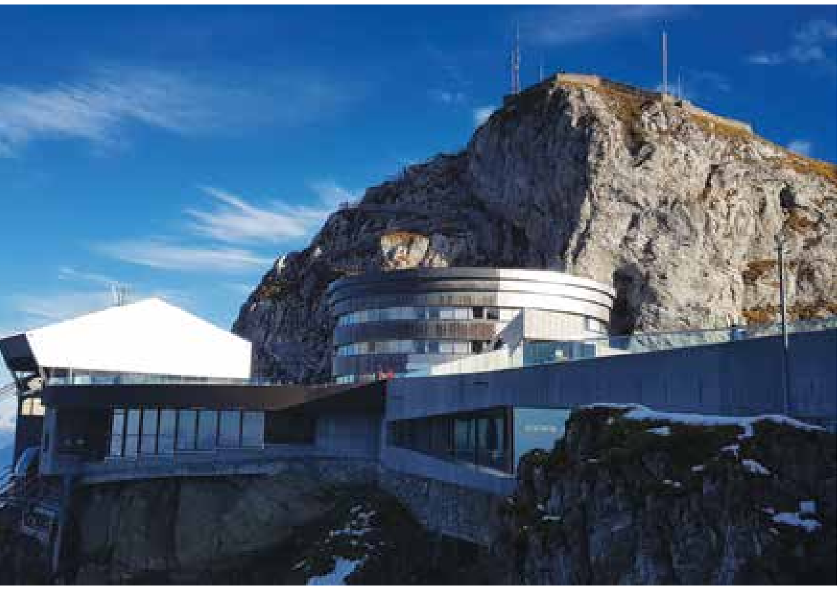


Figure 1: Functional principle of the geothermal probe concept with solar thermal energy (Chilchsteine probe field).



INVOLVED ACTORS

The project was developed in collaboration with Pilatus-Bahnen AG and conducted as part of a Bachelor's thesis at the Lucerne University of Applied Sciences and Arts (HSLU). The work included detailed technical analysis, concept development, and comparative evaluation of energy system options for the Pilatus Kulm buildings.

GOALS

The project defines clear objectives to guide the selection and evaluation of a long-term energy concept for Pilatus Kulm.

- Achieving near-zero emissions in heating and cooling
- Eliminating the need for fossil fuel transport to the site
- Maximizing self-sufficiency through local renewable sources
- Incorporating potential renovation or reconstruction of Hotel Bellevue
- Enabling a structured, comparative evaluation of alternative energy system configuration

STATUS & KEY FIGURES

The project is currently in the evaluation phase. A detailed energy demand analysis has been completed, based on site measurements, operational data, and usage profiles. Multiple system concepts have been developed and assessed through a structured value-benefit analysis in collaboration with Pilatus-Bahnen AG. The analysis compared the ecological performance, economic viability, supply security, and technical feasibility of each option.

Key figures (Geothermal with solar regeneration, planned at the Chilchsteine site):

- 38 geothermal boreholes, each 265 m deep
- 219 MWh/year of extracted heat
- 116 MWh/year of solar regeneration input
- JAZ 3.91 for the main heat pump
- JAZ 5.6 for wastewater heat pump

Key figures (PV and hydrogen concept):

- 4,000 m² PV installation
- 913 MWh/year PV output, with 363 MWh/year used for hydrogen production
- 37,000 Nm³ hydrogen storage (metal hydride tanks)
- 400 kW hydrogen boiler, activated below –2.5 °C
- Electrolyser waste heat: 163 MWh/year, of which 114 MWh used for heating
- JAZ 2.8 for air-source heat pump

BENEFITS AND CHALLENGES

The project illustrates that a high-altitude hospitality site can be operated with minimal emissions using integrated renewable systems. The combination of geothermal energy, solar inputs, and waste heat recovery enables high energy efficiency in a remote and climatically demanding environment. The hydrogen-based system, while more complex, offers flexibility, seasonal storage, and potential for innovation leadership. Challenges include geological uncertainty for deep drilling, coordination with future building development, and the added technical and financial complexity of hydrogen infrastructure. Successful implementation will depend on early-stage risk mitigation and careful alignment of planning and construction timelines.

ECONOMIC FACTS & FIGURES

The evaluated concepts were compared based on total cost of ownership, considering ecological performance, operational costs, and long-term feasibility. While capital expenditures vary depending on the system selected, additional financial advantages are expected from subsidies for photovoltaic and solar thermal installations. These were not included in the original assessment but could significantly improve project viability.

REPLICATION POTENTIAL IN SWITZERLAND

LESSONS LEARNED

- Early coordination with future construction projects is essential to avoid conflicts and delays
- Integrating multiple renewable systems increases resilience, but also requires advanced planning and control strategies
- Detailed geological studies are a prerequisite for deep geothermal solutions
- Innovation potential can be enhanced by identifying suitable flagship applications for public support

This project offers a relevant model for alpine hotels, cable car stations, and other off-grid or hard-to-reach locations with substantial thermal energy demand. Its modular approach — evaluating multiple supply concepts based on site-specific constraints — can be applied to similar mountain tourism infrastructure. The hydrogen concept also demonstrates how energy-intensive sites can serve as pilot cases for sector coupling technologies in extreme environments. ■

Project Example: Ice Storage System – Eggetli, Adelboden

PROJECT DESCRIPTION

The ice storage system combines electricity, heat, and cooling in one integrated concept powered by renewable energy. Designed as a “plus-energy system,” it contributes to Switzerland’s 2050 climate targets by being CO_2-neutral and resource-efficient. Its value lies in addressing the seasonal dilemma: surplus solar energy in summer versus heating demand in winter, and conversely, the need for cooling in summer. By using the phase-change principle of water, the system provides heating during the cold season and passive cooling in summer. In combination with PVT hybrid solar modules, both electricity and thermal energy are produced, maximizing output on limited roof areas.

INVOLVED ACTORS

The Eggetli project is developed by B-Operate AG, which also acts as operator of the future heating system. The heating installation is notarised as condominium property but remains in the ownership of B-Operate AG, ensuring its role as the local heat supplier. Within the same holding, B-Solartec AG provides strategic and technical expertise. As technology partner, PVT Solar AG supplies the hybrid solar modules that combine electricity and thermal generation.

GOALS

The project aims to provide a reliable and climate-neutral energy solution that combines electricity, heating, and cooling in one system, while ensuring long-term economic viability for residents and operators. More specifically, it seeks to:

- Demonstrate a cost-effective and climate-neutral alternative to conventional heating and cooling systems.
- Ensure reliable local energy supply without dependence on external fuels.
- Increase self-consumption through neighborhood-level heat and power distribution.
- Support resilient housing development in mountain regions where no district heating or geothermal probes are possible.

STATUS & KEY FIGURES

The Eggetli housing development in Adelboden consists of 13 chalets with 45 apartments. The project is currently in the permitting phase, with construction planned from 2026 in two stages. Each stage will be equipped with its own ice storage unit and operated as a ZEV (collective self-consumption model).

Key technical data:

- 2 brine-water heat pumps (85 and 55 kW)
- Hot water demand: ~100,000 kWh
- Heating demand: ~159,000 kWh
- PVT modules: 105.6 kWp electrical, 255 kWp thermal
- Additional PV modules: 52.8 kWp
- Ice storage located underground with adjacent technical rooms

Further options under review include wastewater heat recovery and bidirectional e-mobility integration (Vehicle-to-Load / Vehicle-to-Grid).

BENEFITS AND CHALLENGES

The system strengthens local energy autonomy, reduces exposure to volatile prices, and provides a secure long-term heat supply without continuous fuel input. By combining PVT modules with ice storage, both the efficiency of space use and the resilience of the energy system are improved.

The main challenges relate to financing and approval processes:

- Higher upfront investment costs compared to conventional systems
- Limited financing access for small and medium investors
- Lack of thermal subsidies for new installations
- Extensive documentation requirements for subsidies in heating system replacement

ECONOMIC FACTS & FIGURES

Ice storage systems involve higher initial investments. In return, however, they offer stable and predictable operating and amortization costs. Unlike conventional systems, no recurring purchase of fuels is required, which enhances financial security for both operators and consumers. Revenues are generated through the internal sale of thermal and electrical energy within the development, ensuring continuous returns while making residents less vulnerable to volatile energy prices as experienced in recent years.

REPLICATION POTENTIAL IN SWITZERLAND

LESSONS LEARNED

- Proven functionality: existing installations show long-term reliability and economic feasibility.
- Best suited for new buildings, where integration reduces costs and complexity.
- Retrofitting requires full renovation to reduce demand and ensure economic viability.
- Space availability is often the limiting factor, as storage size scales linearly with demand.
- From an energy demand area of ~800 m² upwards, ice storage becomes economically attractive.

Ice storage systems are particularly suited for larger residential complexes, industrial buildings, and neighborhood-scale developments. They are also a sustainable alternative in locations where geothermal probes cannot be drilled, or district heating is unavailable. With increasing requirements for energy autonomy and CO_2 reduction, such systems can play a key role in local energy strategies, especially when integrated from the outset in new construction projects. ■

Project Example: Victorinox Swiss Army SA

Victorinox Swiss Army SA decided to expand its two factories in Delémont in order to bring together knife production and watch assembly activities on a single site. This was an opportunity to implement a renovation plan for the existing installations and buildings, with the aim of improving climatic conditions for employee comfort and production quality, while reducing CO2 emissions, energy costs and water consumption.
These ambitious objectives have been achieved thanks to the overall coherence of all the actions undertaken, starting with in-depth knowledge of the energy consumption, production and losses of buildings, utilities and industrial processes. A Pinch analysis of the various thermal and electrical flows identified flows that could be combined to reduce final energy requirements. In particular, the cooling circuit for the cutlery factory's machine tools was measured and its flow rate adapted. This made it possible to increase its temperature to become a better source of heat for the future thermo-fridge-pump. This same circuit, previously supplied mainly by spring water, was looped, drastically reducing the plant's water consumption.

When the plant requires simultaneous cooling for machine tools and heat for ventilation, the heat pump produces cooling and heat with an overall coefficient of performance (COP) of 9.

At the same time, the ventilation systems were completely overhauled to ensure air quality and better control of climatic conditions. Ventilation rates were adapted to actual requirements and heat recovered, thereby reducing heat consumption. Heat consumption has been further reduced

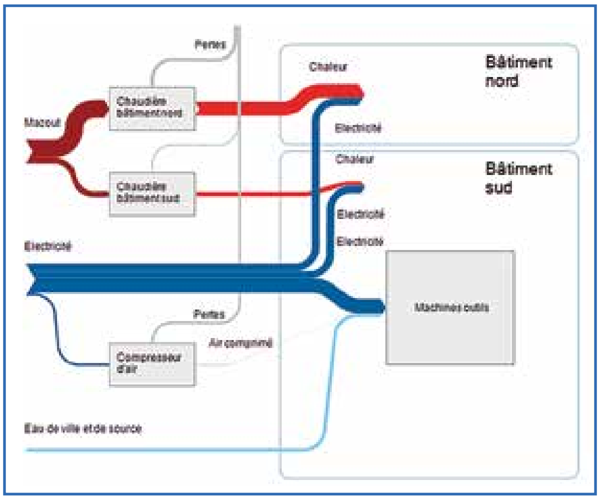


Figure 1: Situation before energy renovation: high losses, high CO2 emissions and high consumption of fuel oil and city water

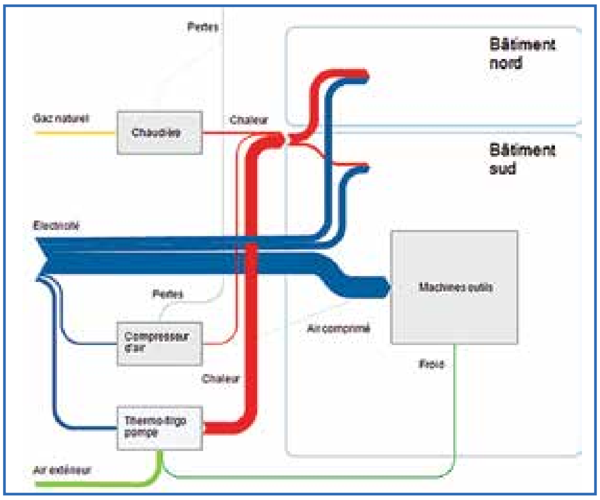


Figure 2: SSituation after energy renovation: Fossil energy consumption and CO2 emissions reduced by 90% and city water consumption reduced by 80%

by completely replacing the facades and roof of the southern plant, and by recovering heat from the air compressors. A photovoltaic solar system has also been installed on all the roofs of the site. This approach, which lasted several years, enabled us to reduce fuel oil consumption by 155,000 litres/year, a 90% reduction, and at the same time to reduce CO2 emissions by 390 to/year and water emissions by more than 20,000 m3/year, a reduction of 80%.

ECONOMIC FACTS & FIGURES

This project is related to the conversion/expansion of a factory. The total cost of the work amounts to some CHF 5,435 millions (technical installations only).

LESSONS LEARNED AND REPLICATION POTENTIAL IN SWITZERLAND

This project shows how, through a global approach and in-depth knowledge of their needs, companies can successfully decarbonise their own infrastructure (scope 1) while improving comfort and service levels for occupants and processes.

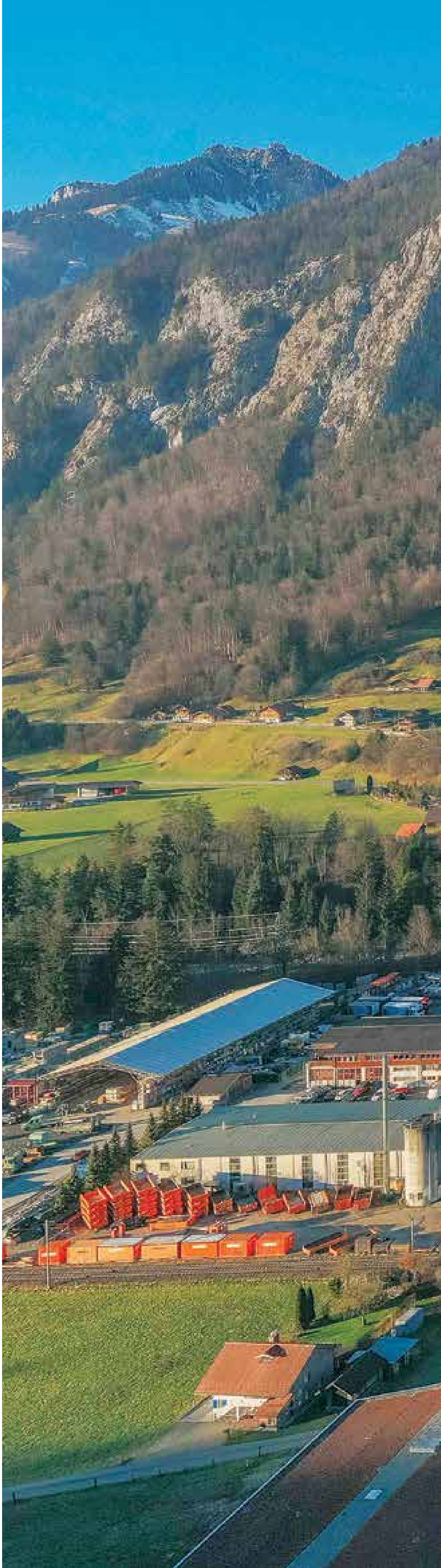
This approach is applicable to virtually all industrial companies that produce waste heat, for example the heat dissipated by refrigeration units, air compressors or production equipment.

This approach does not require any regulatory changes, but it does require skills within the company to understand what is at stake and to manage a multi-faceted project throughout its life, from the initial concept to the optimisation of installations, including budget planning for all operations.

As for “waste heat”, which comes from companies that produce far more heat than they need, it can be used as a source of heat to supply other consumers, either directly or via heat pumps. In this case, it is essential for local authorities to plan structuring networks - district heating and/or cooling - as well as mechanisms for financing and guaranteeing the delivery of waste heat. ■

Scope level: Area

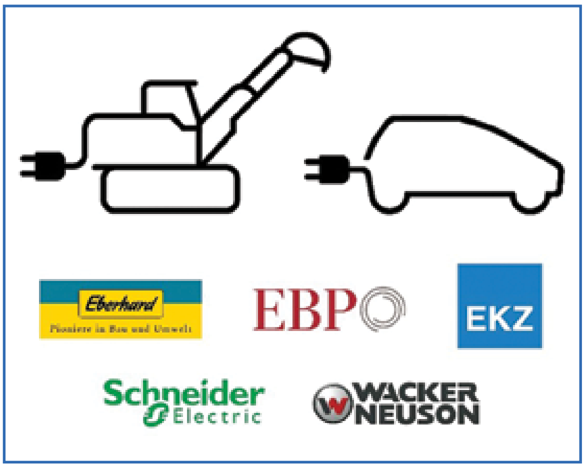
From January 1, 2026, Switzerland's revised electricity law will enable Local Electricity Communities (LEGs), allowing locally produced solar power to be used on-site or sold directly to nearby consumers. This opens new opportunities for industrial areas, commercial facilities, and mobility providers to improve energy self-sufficiency and reduce grid dependency, often with better returns than traditional feed-in tariffs. The revised legislation fosters a favourable environment for integrated projects that combine rooftop photovoltaic systems, e-charging infrastructure, e-mobility solutions, energy management, and local partnerships between private enterprises and energy distributors.



Project Example: Local electricity community in an industrial Zone, Eberhard Bau AG

PROJECT DESCRIPTION

The project centres around the installation of public EV charging infrastructure on the industrial premises of Eberhard Bau AG in Rümlang (ZH). These charging stations are powered by solar energy from the company's own photovoltaic systems and integrated into a legally compliant Local Electricity Community. Bringing together PV systems, EV charging stations and a smart energy management platform, the project demonstrates the components of a decentralized, intelligent energy system while enabling direct electricity sharing with neighbouring properties and public users. Eberhard's motivation is closely tied to the scale of its operations: with a fleet of roughly 100 passenger vehicles, 100 trucks, and 200 construction machines, the company consumes the energy equivalent of around 50 million kilowatt-hours in fuel annually. Transitioning to electrification and renewable supply therefore represents a key step in decarbonizing of its operations.



INVOLVED ACTORS

The planning and implementation of this project requires close collaboration among various stakeholders, including planning firms (EBP), energy providers (EKZ), technology partners (Schneider Electric), regulatory authorities (BFE) and project developers (Eberhard).

GOALS

The objective of the project is to establish publicly accessible EV charging stations on Eberhard industrial sites, based on solar energy. By leveraging cross-systems, AI-supported technologies, the project creates added value through intelligent energy management and the strategic expansion of charging infrastructure with a Local Electricity Community.

STATUS & KEY FIGURES

The project is structured into six phases:

a.) Concept development and feasibility study,
b.) Development of business and organizational models and clarification of financing,
c.) Technical planning and tendering,
d.) Construction and commissioning,
e.) Test operation and communication, and
f.) Roll-out.

The implemented charging infrastructure includes:

- 2 to 4 AC charging points, each with a capacity of 22 kW.
- 1 DC charging station with 2 charging points, each capable of 100 kW in dual mode or 200 kW in single mode.

The backend and billing provider combines customized services for the setup and operation of a system to manage and monitor the client's charging infrastructure. This includes all the processes necessary for managing charging customers and processing payments for charging sessions. It also covers collection of charging fees for both semi-public and public use of the infrastructure.

BENEFITS AND CHALLENGES

Local Electricity Community increases self-consumption and reduces electricity costs by enabling direct use of surplus solar power within communities. It also supports net zero goals and opens up new business opportunities without requiring additional grid infrastructure.

ECONOMIC FACTS & FIGURES

The total investment for the charging infrastructure is approximately CHF 300,000, excluding photovoltaic systems. The combination of lower energy costs, optimized self-consumption, and potential public charging revenues supports a financially sustainable business model.

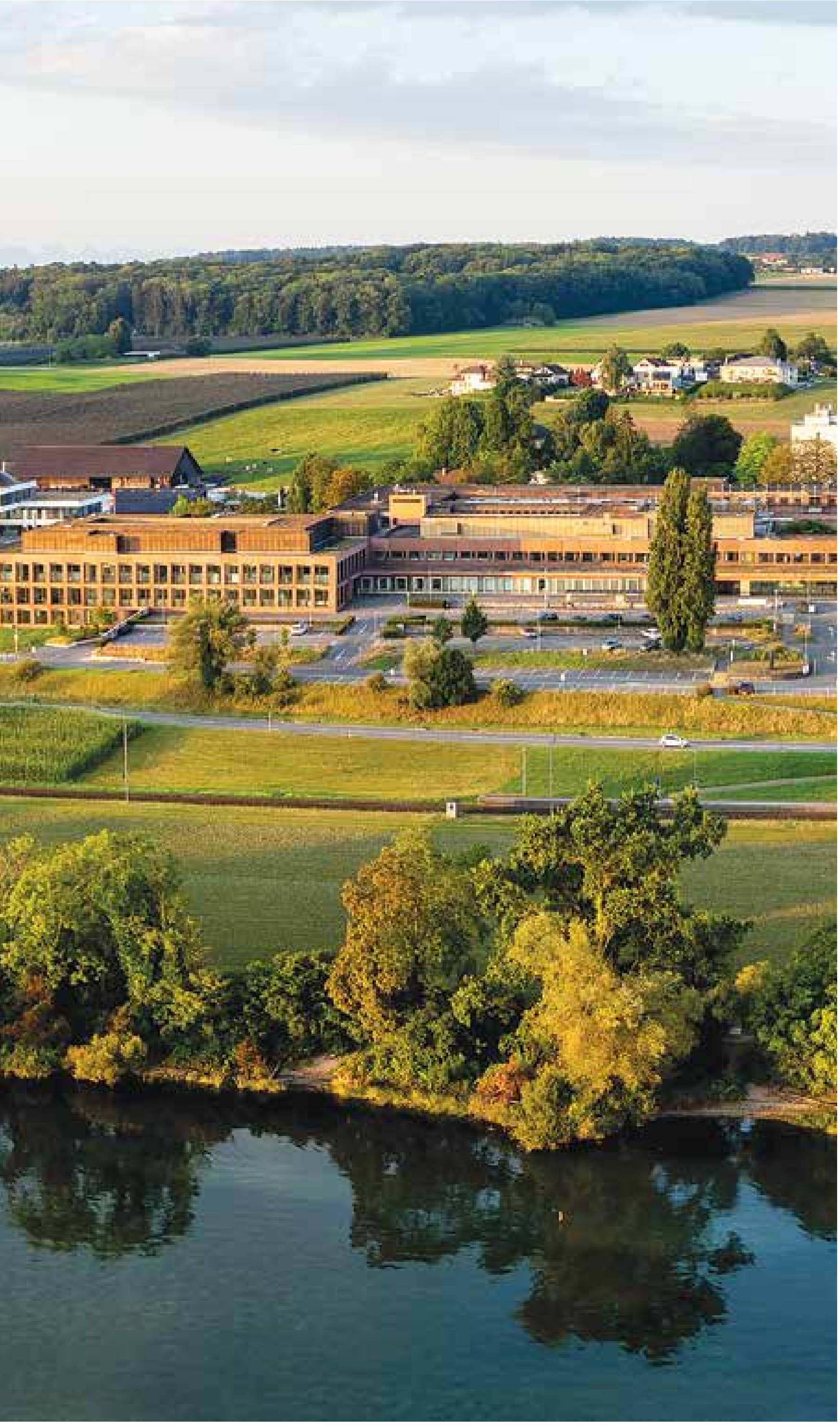
REPLICATION POTENTIAL IN SWITZERLAND

LESSONS LEARNED

- Cross-sector collaboration brings together valuable expertise from energy providers, technology suppliers, construction firms, and consultants.
- Structured, regular meetings enable fast decision-making and foster innovative problem-solving.
- Open and honest communication builds trust and ensures shared understanding of goals and expectations.
- Thorough evaluation of locations and options allows for technically and economically sound decisions.
- Clear tender documents lead to well-structured and comparable offers.
- Early risk mitigation helps focus on core project elements and reduces uncertainty.
- Business model development clarifies roles, responsibilities, and financial viability for all stakeholders.
- Flexibility in site selection remains essential as conditions evolve during the project.

Similar configurations can be extended to parking infrastructure, cable car operators, leisure parks, and retail environments. ■

Project Example: Campus Münsterlingen, thurmed AG



PROJECT DESCRIPTION

The Münsterlingen Campus decarbonization project aims to reduce on-site CO_2 emissions to net zero by 2050. The campus, which hosts both a cantonal hospital and a psychiatric clinic, is a complex and energy-intensive environment. Thurmed Immobilien AG, a subsidiary of thurmed AG (owned by the Canton of Thurgau), initiated the project in line with Switzerland's long-term climate targets and the canton's role as a public-sector role model. Measures include decarbonizing the heat supply, electrifying sterilization processes, expanding solar power generation for self-consumption, and applying sustainable construction standards that address embodied carbon in future buildings.

INVOLVED ACTORS

The project is driven by a cross-functional team from the thurmed Group (specialists in sustainability, energy procurement, facilities management, and project coordination) and EBP (for energy system design including geothermal probes and analysis). A geologist recently joined the team to examine the local geology for geothermal probes.

GOALS

The initiative seeks to demonstrate that complex, historically developed sites can be decarbonized. Core objectives include:

- Phasing out fossil-based heating systems through geothermal energy
- Electrifying high-temperature steam processes
- Producing solar electricity for on-site use
- Applying low-emission construction methods in all future developments.

STATUS & KEY FIGURES

The project is currently in the feasibility phase, with a focus on dimensioning geothermal probe fields to meet future heating and cooling needs. Internally, options for electrifying the existing gas-fired steam infrastructure are under review, as high-temperature process heat is still generated with conventional boilers.

- Expected CO_2 savings: approx. 4,300 tonnes per year

BENEFITS AND CHALLENGES

The project will establish a fossil-free energy supply for the Münsterlingen Campus, reducing energy consumption and contributing directly to Switzerland's 2050 climate goals. It also offers long-term cost stability and serves as a replicable model for other healthcare facilities.

However, implementation poses technical and organizational challenges. The electrification of legacy steam systems is complex and must be managed without disrupting hospital operations.

Phased planning and open communication are essential to ensure continuity of services and manage expectations across departments. Long-term project continuity will also require strong internal alignment and resilience through potential leadership changes.

ECONOMIC FACTS & FIGURES

Initial investments of approx. CHF 20 mill. focus on geothermal and solar infrastructure. Future stages — such as building envelope retrofits and steam system electrification — will require further capital but are expected to improve overall operating efficiency.

REPLICATION POTENTIAL IN SWITZERLAND

LESSONS LEARNED:

- Interdisciplinary collaboration is key to balancing technical goals with operational needs
- Early-stage feasibility must assess site-specific constraints and long-term maintainability
- Maintaining momentum through clear governance and stakeholder engagement is essential
- Project flexibility allows for recalibration as conditions or personnel evolve

The Münsterlingen Campus serves as a strong example of how large-scale medical campuses — with historical building stock and intensive energy demands—can begin structured decarbonization. The Methodology is relevant for other public healthcare campuses and institutional portfolios throughout Switzerland. ■

Project Example: Serial Net Zero Building Renovation

PROJECT DESCRIPTION

This project introduces a scalable model for net zero building renovation, designed to overcome the high costs, complexity, and inefficiencies of conventional approaches. Instead of fragmented, trade-by-trade execution, it applies a standardized and lifecycle-oriented method that integrates the building envelope, heating replacement, local solar energy production, and charging infrastructure. Based on serial renovation models from Germany and the Netherlands, the concept is adapted to Swiss conditions to accelerate and simplify net zero modernization by standardization and industrialization. It was initiated to address the shortcomings of traditional renovations, which are often fragmented, error-prone, and costly, lacking lifecycle optimization, coordination and organization as well asknowledge transfer between planning, execution, and operation.

INVOLVED ACTORS

The building renovation projects are developed together with Tend AG, which acts as the central integrator and coordinates all relevant trades and processes. The buildings are privately owned, with property owners benefiting from lower costs due to standardization, reduced coordination effort and lower implementation risks.

GOALS

The main objectives are to deliver fast and reliable building renovations that prepare buildings for net zero by:

- Replacing fossil heating systems with renewable technologies
- Local solar production by photovoltaic installations
- Integral building optimization including energy efficient building envelope

- Optimization of energy prosumption by an overall energy management system
- Offering a one-stop-shop model with fixed-price guarantees

STATUS & KEY FIGURES

Pilot projects have been realized and apply the systematic renovation model in practice. The focus on multi-family housing creates efficiencies in approval and implementation, while the standardized process reduces risks and coordination effort for owners.

- Project status: pilot projects realized
- Building type: multi-family residential, office buildings
- Technologies: heat pumps, Photovoltaic with inverters, e-mobility charging, energy management systems
- KPIs: CO_2 savings, reduced investment and operating costs, and reduced ancillary costs

The model builds on experience from earlier efforts, which demonstrated how public backing and standardized processes can raise renovation rates and reduce risks for owners.

BENEFITS AND CHALLENGES

The systematic renovation model offers clear advantages for property owners: one central contact point replaces fragmented and inefficient coordination, fixed-price contracts provide cost and

schedule security, and standardized processes ensure lower investment cost as well as reliable operation with low running costs. In addition, the approach prepares buildings for future technologies such as storage, e-mobility, and smart operation as well as energy net-friendly operation and variable energy rates.

The main challenges for broader implementation are:
- current procurement processes of property owners
- complex approval and permitting procedures

A central point of contact can simplify coordination and reduce the effort required from property owners.

ECONOMIC FACTS & FIGURES:

The economic basis of the systematic renovation model lies in efficiency gains from efficient project organization, process standardization, prefabrication, and fixed-price implementation. While comprehensive CAPEX and OPEX figures from pilots are still being consolidated, the approach is designed to lower overall investment and operating costs compared to traditional renovation methods. Property owners benefit from predictable expenses, which ends up in greater financial security, reduced ancillary energy costs which ends in higher real estate value, while risks are minimized through proven processes and contractual guarantees.

REPLICATION POTENTIAL IN SWITZERLAND

LESSONS LEARNED:

- A single contact point simplifies coordination and reduces the effort and decisions required from property owners
- Lifecycle optimization across all trades improves cost and energy efficiency as well as reliability
- Proven, durable products reduce technical and financial risks
- Monitoring supports reliable operation and long-term performance
- Prefabrication lowers costs and ensures quality
- Clear assignment of execution risk to the system integrator is essential

The systematic renovation model can be widely replicated, particularly in multi-family housing, where CO_2 reduction potential is highest. By applying standardized methods and fixed-price contracts, the approach reduces complexity and accelerates implementation. Its scalability makes it attractive not only for private and institutional owners, but also for cooperatives and municipalities, offering both improved cost-efficiency and reduced environmental impact. ■

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Project Example: Microgrid Les Cèdres, Romande Energie

PROJECT DESCRIPTION

The Microgrid Les Cèdres, located in the new eco-district of Chavannes-près-Renens near Lausanne, demonstrates how local renewable energy can be maximized at community scale. Led by Romande Energie, the project integrates photovoltaic production, geothermal heat pumps with thermal storage, and a smart energy management system across three residential buildings and a supermarket. In operation since 2019, it reduces dependence on the public grid by enabling local electricity sharing within a legally compliant framework. The project shows how microgrids can provide tangible ecological and economic benefits in dense urban environments, paving the way for broader sector coupling in Swiss cities.

INVOLVED ACTORS

The project was initiated and is operated by Romande Energie SA, which acted as the main project leader and investor. Electrical infrastructure was delivered by Arnold AG, while the real estate development was carried out in partnership with Groupe Orllati SA, Helvetia Group, and other developers involved in shaping the eco-district. This close collaboration between an energy utility, infrastructure provider, and property developers created the framework for a fully integrated microgrid solution that balances residential and commercial needs.

GOALS

The project was designed to demonstrate how a community-scale microgrid can combine renewable production, intelligent management, and cost efficiency. Its objectives are centered on both technical optimization and broader urban energy transition:

- Maximize local self-consumption of photovoltaic electricity across the eco-district.
- Enable load shifting by using thermal storage and smart control systems.
- Demonstrate ecological and economic potential of energy communities in dense urban settings.


©Romande Energie

STATUS & KEY FIGURES

Having entered into operation in 2019, the microgrid now supplies both residential and commercial users. Early results confirm the expected performance in terms of energy balance and efficiency.

- First phase: 6 buildings, including 284 apartments and 1 supermarket
- Installed PV capacity: 234 kWp
- Heating: geothermal heat pumps with thermal storage
- Self-sufficiency: 24% of district electricity demand
- Self-consumption: 96% of locally produced PV
- CO_2 reduction: up to 16% compared to individual building solutions
- Cost reduction: up to 18% compared to individual building solutions

BENEFITS AND CHALLENGES

The pilot confirms that pooling energy production and demand within a microgrid generates clear value for both users and the wider grid. At the same time, the project highlights structural and regulatory barriers that need to be addressed.

BENEFITS

- Increased local energy autonomy
- Reduced grid load during peak demand hours
- Lower operating costs through optimized system management

CHALLENGES

- Complex regulation of local grid ownership and billing
- High upfront investment requirements for smart infrastructure
- Balancing diverse load profiles between residential and commercial users

ECONOMIC FACTS & FIGURES

The total investment for the project amounted to CHF 998,000, with annual operating costs of around CHF 32,000. Thanks to high levels of self-consumption, the system reaches a payback period of roughly 16 years, while supplying electricity at a local tariff of CHF 0.13/kWh. Compared to conventional individual building solutions, the microgrid reduces CO_2 emissions by up to 16% and lowers energy costs by up to 18%.

©Romande Energie

REPLICATION POTENTIAL IN SWITZERLAND

LESSONS LEARNED:

- Private microgrids can deliver tangible ecological and economic advantages when multiple buildings are integrated.
- Smart control and thermal storage are essential to balance daily and seasonal fluctuations in PV-dominated systems.
- Early alignment between utilities, infrastructure providers, and property developers is critical for smooth implementation.
- Regulatory clarity on local grid ownership and billing remains a decisive factor for long-term success.

The Microgrid Les Cèdres highlights how new urban developments can integrate renewable generation, storage, and intelligent control into a coherent local energy system. With the revised electricity law providing clearer rules for grid sharing and tariffs, similar projects can be replicated across Switzerland, particularly in eco-districts and large-scale housing projects. The new framework also opens possibilities for adapting such models to existing building blocks, provided legal and technical conditions are met. The model demonstrates not only technical feasibility but also cost-effectiveness, offering municipalities and developers a blueprint for reducing emissions and advancing sector coupling in dense urban areas. ■

Project Example: Sector Coupling, Dyno AG

PROJECT DESCRIPTION

Dyno AG is implementing a site wide sector coupling concept at its Bernese Midlands headquarters to make energy supply more sustainable, cost efficient, and independent. Existing assets (a heat pump and an on site small hydropower unit) are being integrated with a new rooftop PV array, a PV façade to boost winter yield, and a planned battery storage system. An energy management system (EMS) will coordinate electric and thermal flows so surplus solar/hydro power can serve heat production, charge the battery, or supply EV charging. With storage in place, balancing services will be offered via partner Swiss Renewable Solutions to create additional revenue and support grid stability.

INVOLVED ACTORS

Dyno AG leads as owner–operator of the buildings and the on site hydropower plant (industrial metal processing, from design and sheet metal work to welding, machining, surface treatment, assembly, and commissioning). Swiss Renewable Solutions partners on planning, financing, construction, and operation of PV and battery installations and will market balancing capacity.

GOALS

The project seeks to establish a fully integrated, future-proof energy system that aligns economic efficiency with sustainability and resilience. In particular, it aims to:

- Reduce energy costs and exposure to volatile markets
- Increase self-sufficiency through renewable energy generation
- Improve winter electricity production with PV façade installations
- Enable flexibility and balancing services for the grid
- Prepare the site for a transition to zero-emission mobility

STATUS & KEY FIGURES

The project has progressed well beyond the concept phase, with several technologies already in operation and others under construction or in planning. This mix of implemented and upcoming measures illustrates a step-by-step approach toward full sector coupling:

- PV rooftop and façade: under implementation
- Heat pump and hydropower plant: in operation
- Battery storage and EV charging: in planning

ANNUAL ENERGY DATA

- PV generation: ~600 MWh (roof and façade combined)
- Hydropower generation: ~60 MWh
- Electricity demand: ~485 MWh
- Share from PV: ~30%, scalable to >50% with storage
- Share from hydropower: ~12%
- Heat demand: ~300 MWh (supplied via heat pump, included in electricity demand)

BENEFITS AND CHALLENGES

By integrating hydropower, PV systems, and a heat pump, Dyno AG is already reducing purchased electricity, lowering exposure to volatile market prices, and contributing to climate goals. The planned storage system and façade PV will further improve self-sufficiency, support grid stability, and enable a transition toward zero-emission mobility. CO_2 savings are already being achieved through the heat pump and will further increase with the integration of e-mobility.

The main challenges lie less in technology and more in practical implementation factors:

- Long investment horizons and roof renovation requirements, partly mitigated through PV contracting by Swiss Renewable Solutions
- Limited space for storage units and employee parking
- Complex system integration under one energy management platform
- Regulatory hurdles for storage, façade PV, and grid feed-in
- High demands on signal integration, including market data, weather forecasts, and thermal needs

ECONOMIC FACTS & FIGURES

The economic foundation of the Dyno AG project is built on a long-term approach that combines contracting solutions with operational savings. The PV contracting model provided by Swiss Renewable Solutions reduces the need for upfront capital and enables implementation of the solar installations despite the scale of investment. Substantial cost savings result from the on-site generation of electricity through PV and hydropower, while the planned battery storage system will additionally open access to flexibility and balancing energy markets. Investments are structured as long-term commitments and amortised over several years, with PV contracting lowering upfront capital requirements. Together, these elements create a stable business case that balances financial returns with long-term sustainability.

REPLICATION POTENTIAL IN SWITZERLAND

LESSONS LEARNED:

- Technical feasibility is not the problem; financing and regulation are decisive.
- Switzerland lacks financing instruments like Germany's KfW (Kreditanstalt für Wiederaufbau – state development bank), which limits implementation despite proven technical maturity.
- Missing feed-in remuneration reduces investment security despite one-off subsidies.
- Uncertainty over roof durability, energy prices, and fleet electrification delays decisions.
- Even when projects are approved, implementation is frequently delayed by grid operators and local administrations, even where legal foundations are already in place.

Scaling this type of sector coupling project across industrial and commercial sites could significantly relieve pressure on electricity grids, reduce reliance on fossil fuels, and strengthen overall energy resilience. By linking electricity and heat production, load peaks can be managed more effectively, flexibility services for grid operation can be provided, and CO_2 emissions can be cut on a broader scale. The integration of e-mobility further enhances self-consumption and contributes to decarbonizing the transport sector, while at the same time increasing the attractiveness of companies as employers. ■

Project Example: Plusenergiestadt Burgholz

PROJECT DESCRIPTION

The Plusenergiestadt Burgholz initiative, launched by the Canton of Bern, aims to transform the Burgholz industrial zone into a district that generates more energy than it consumes. Covering nearly 8 hectares north of the BLS railway line and 1.4 hectares south of it, the area includes companies such as Mühle Burgholz and Naturpark Käserei Simmental. Current annual demand amounts to around 8 GWh of electricity and 7 GWh of heat, with electricity sourced individually from the national grid and heat supplied partly by a local district heating network and partly by building-specific systems. By leveraging existing infrastructure alongside local biomass and solar energy, the project seeks to demonstrate how decentralized, community-driven energy systems can achieve carbon reduction and energy independence. As a lighthouse initiative for the regional energy transition, it is intended to serve as a replicable model for climate-conscious industrial zones.

INVOLVED ACTORS

The project involves a wide range of local businesses, landowners, and energy users. It is being supported by Green Energy Venture in the areas of concept development, project managementand stakeholder coordination, particularly in facilitating collaboration among companies and exploring viable legal and financial models. As the project progresses, further cooperation with planning authorities and community representatives will be essential. The success of the initiative depends heavily on strong local stakeholder engagement.

GOALS

The aim is to implement a holistic and integrated energy system by:

- Installing solar PV systems across the industrial zone
- Producing heat and electricity with local biomass resources
- Creating local renewable electricity distribution mechanisms
- Integrating battery energy storage systems (BESS) if required for load balancing

STATUS & KEY FIGURES

The project has advanced beyond the initial concept stage and is now in active stakeholder engagement and early implementation planning. Technical options have been outlined, and local companies are being consulted regarding their participation. Parallel work is being done to enhance project communication identify subsidy opportunities.

- Electricity demand: approx. 8 GWh/year
- Heat demand: approx. 7 GWh/year
- Estimated CAPEX: ~CHF 10 million (taking into account of subsidies and excluding BESS)
- Projected OPEX: ~CHF 0.7 million/year, mainly due to biomass feedstock
- Estimated energy cost savings: ~70% compared to conventional systems
- Payback period: 6–7 years

BENEFITS AND CHALLENGES

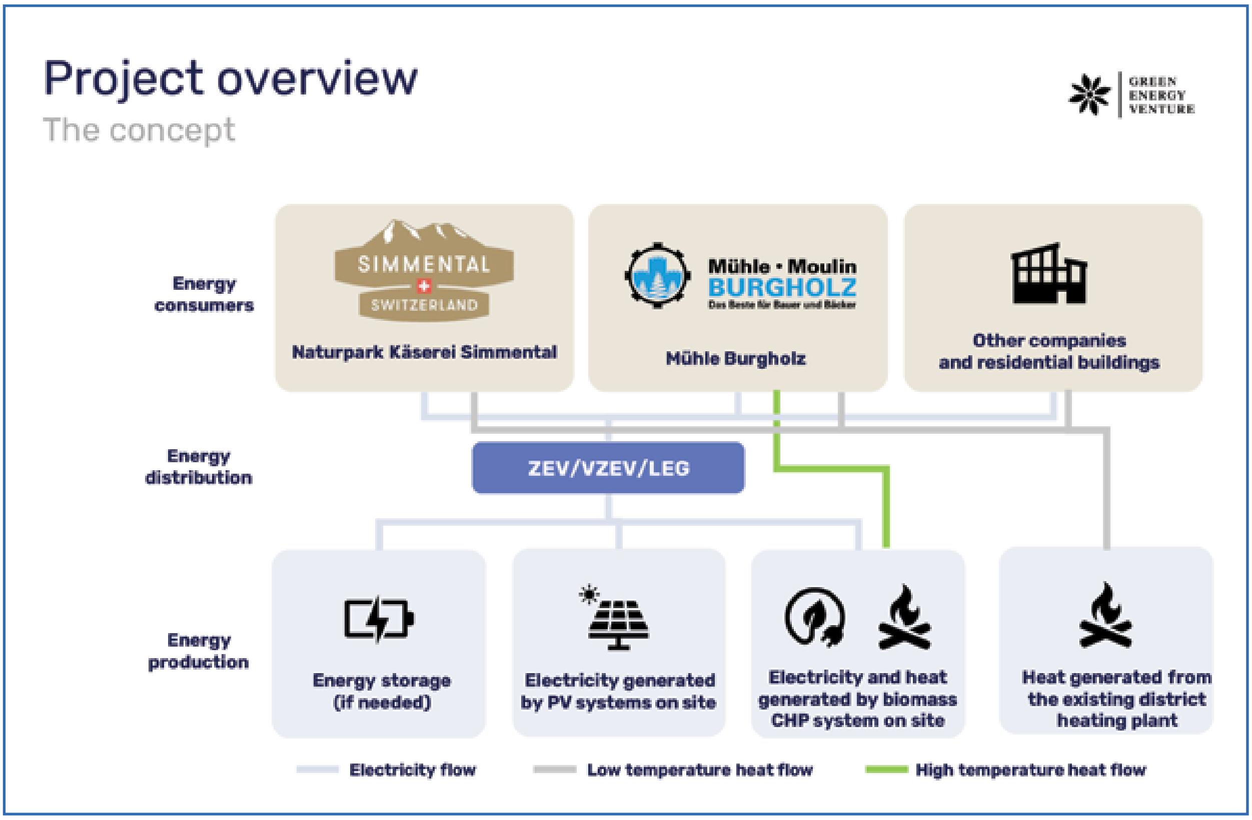
The project offers lower energy costs, increased energy independence, carbon reductions, and potential property value gains. Broader community benefits include support for local biomass usage and greater self-sufficiency.

However, challenges remain:

- Reluctance to invest in PV and heating system upgrades
- Resistance to forming cooperative models like LEG or VZEV
- General scepticism toward new technologies and regulatory frameworks

ECONOMIC FACTS & FIGURES

With an estimated CAPEX of CHF 10 million, the business case is supported by subsidies and long-term operational savings. The OPEX of CHF 0.7 million is mainly driven by biomass feedstock costs. Assuming a lifetime of 25–30 years for solar installations and 20 years for the CHP plant, the system is expected to deliver both financial and environmental returns.



Project overview

The concept

Practical experience shows that area-level energy projects require more than technical solutions. Coordinating multiple actors, overcoming investment hesitation, and establishing shared operating models remain key barriers—especially when upgrading functioning systems or introducing new legal structures like LEG or VZEV. For these initiatives to scale, structured support is needed: not only in planning and technology, but in guiding collaboration, reducing administrative burden, and creating a reliable framework for joint implementation.

REPLICATION POTENTIAL IN SWITZERLAND

LESSONS LEARNED:

- Decentralized systems require early and ongoing stakeholder buy-in
- Demonstrating both financial and environmental benefits is key to participation
- Tailored advisory services can help address concerns and overcome resistance
- Flexibility in planning supports broader adoption and long-term success

This project illustrates how mixed-use zones—especially those with industrial and small commercial activity—can transition to sustainable energy through locally available resources. With new legal frameworks such as VZEV and LEGs, other municipalities can apply similar models to drive cost-effective, decentralized energy transitions. ■

Scope level: Municipality

Municipalities play a central role in Switzerland's energy transition — both as infrastructure owners and as initiators of climate-resilient solutions. The following projects showcase how local authorities are driving forward innovative energy concepts, often in partnership with private actors and residents. From decentralized heat supply to integrated energy planning, these initiatives are scalable, replicable, and aligned with long-term net zero targets.

Project Example: Impact of Heat Pump Based on Urban Heating Transition

PROJECT DESCRIPTION

This project investigates the impact of integrating power-driven heat pumps (HPs) into urban heating systems on the stability of local electricity distribution grids, using the city of Yverdon-les-Bains (VD) as a test case. The study reflects wider European trends, where the replacement of oil and gas boilers is driven not only by decarbonization policies but also by the need to reduce local air pollution in urban areas. As fossil-fuel boilers are replaced with HPs in line with national and local decarbonization policies, winter electricity demand increases significantly, raising concerns about under-voltage and grid congestion in existing low- and mid-voltage networks. To assess these risks, researchers at HEIG-VD developed a Python-based simulation environment that enables precise hourly power flow analysis under different cold-weather scenarios. The study compares transition pathways—ranging from large-scale HP deployment to mixed systems incorporating combined heat and power (CHP)—and shows that while heat pumps are central to decarbonization strategies, their widespread use can challenge grid stability unless complemented by CHP or targeted grid reinforcements. The methodology is designed to be transferable to other urban territories with dense electricity and gas grids, supporting evidence-based planning beyond the Yverdon-les-Bains case.

INVOLVED ACTORS

The project was led by HEIG-VD (Institut des Energies) and supported by the local energy provider Services des Energies de la Ville d'Yverdon-les-Bains (SEY).
Key contributors include Prof. Massimiliano Capezzali, Prof. Mokhtar Bozorg, and Marten Fesefeldt.

GOALS

The objective is to analyze the technical implications of different heating system transition pathways in urban areas and identify grid-compatible solutions. Particular focus was placed on understanding how coordinated integration of CHP units, reinforcement measures, and PV inverter-based reactive power management can help stabilize the electricity grid under increased winter load.

STATUS & KEY FIGURES

The project is completed. The developed Python-based simulation environment is fully operational and adaptable to other urban territories with dense electricity and gas infrastructure.
Key findings from the Yverdon-les-Bains test case

INCLUDE

- The current distribution grid is well dimensioned for existing loads and can even handle short-term demand peaks.
- However, a full transition to heat pumps would lead to:
  - Under-voltage at several buses
  - Overloading in a number of low-voltage lines
- Installing CHP units in place of gas boilers proved to be a possible solution to cover an increasing electricity demand coming from the transition to heat pumps.
  - CHP electricity production aligned well with winter HP demand
  - Under-voltage issues were reduced by approx. 0.05 p.u.
- Grid reinforcement (e.g., replacing cables or lowering resistance) reduced line loading but did not significantly resolve under-voltage problems.
- Reactive power injection via PV inverters mitigated voltage drops but increased line loading.

Integration on Power Distribution Grids Scenarios Including CHP

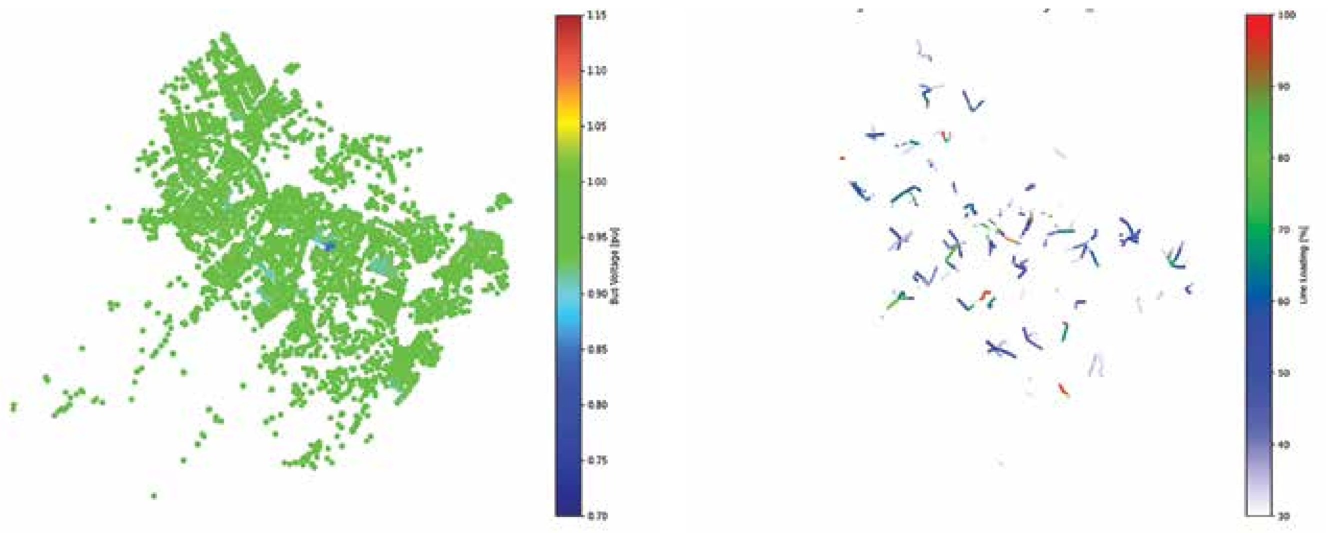


Figure 1. Grid bus distribution of voltage and line loading at 20pm on a typical winter day in the full heat-pump scenario.

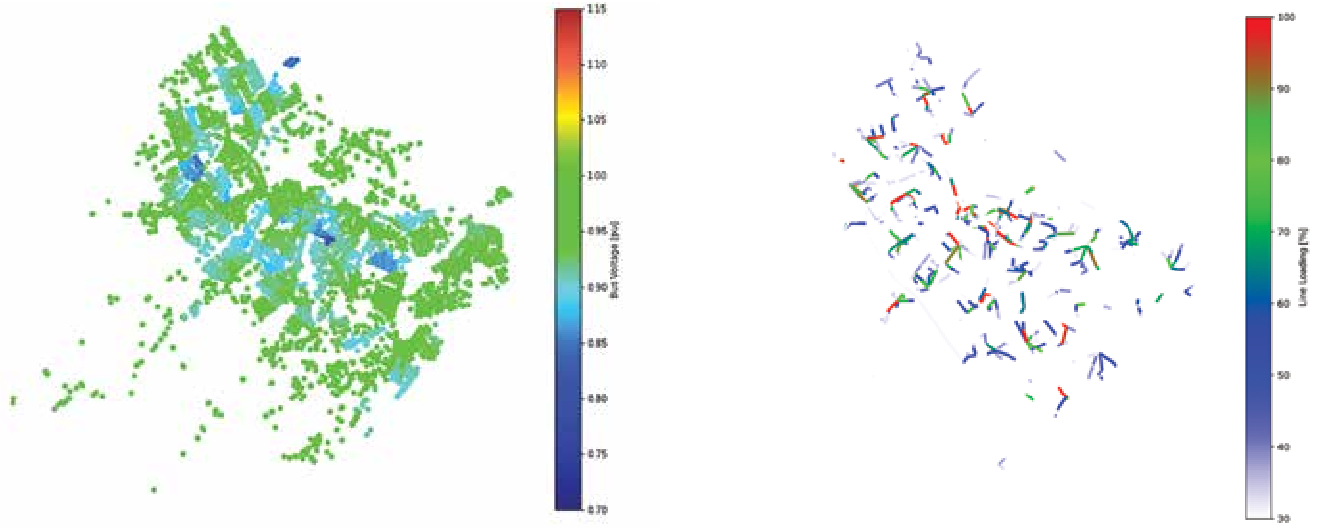
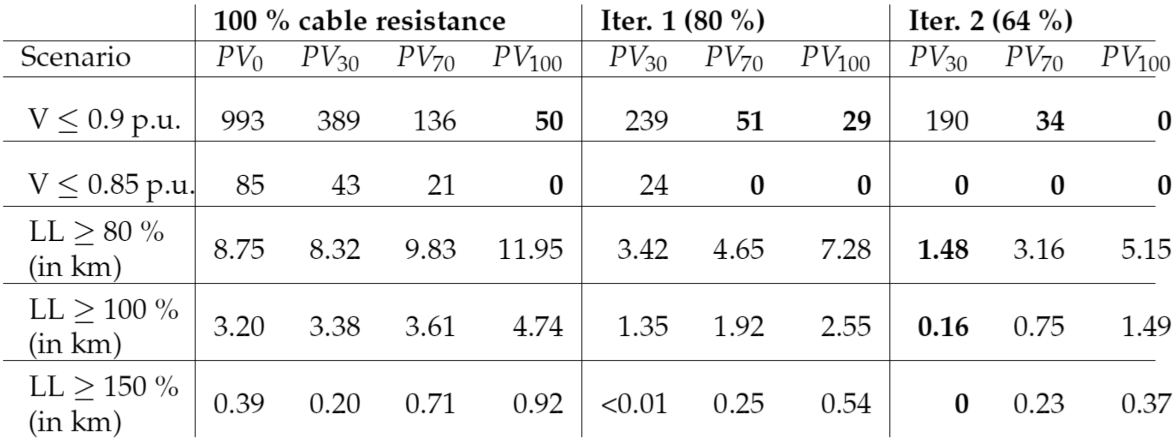


Figure 2. Grid bus distribution of voltage and line loading at 20pm on a typical winter day in the mixed cogeneration + heat-pump scenario.

- PV represents an interesting solution for voltage control, however more focused control strategies have to be implemented and a better communication with the converter have to be developed to solve the voltage variation in a more efficient way.

Among the studied options, CHP + HP coordination was shown to be the most balanced pathway, while reinforcement and PV reactive power provided only partial relief.



	100 % cable resistance				Iter. 1 (80 %)			Iter. 2 (64 %)		
Scenario	PV_0	PV_{30}	PV_{70}	PV_{100}	PV_{30}	PV_{70}	PV_{100}	PV_{30}	PV_{70}	PV_{100}
$V \leq 0.9$ p.u.	993	389	136	**50**	239	**51**	**29**	190	**34**	**0**
$V \leq 0.85$ p.u.	85	43	21	**0**	24	**0**	**0**	**0**	**0**	**0**
$LL \geq 80$ % (in km)	8.75	8.32	9.83	11.95	3.42	4.65	7.28	**1.48**	3.16	5.15
$LL \geq 100$ % (in km)	3.20	3.38	3.61	4.74	1.35	1.92	2.55	**0.16**	0.75	1.49
$LL \geq 150$ % (in km)	0.39	0.20	0.71	0.92	<0.01	0.25	0.54	**0**	0.23	0.37

Table 1 . Influence on the line loading and voltage level of injecting reactive power by the proposed installed photovoltaic systems (with values in bold lower than in the current state scenario.

BENEFITS AND CHALLENGES

The project provides a transferable and data-driven methodology to evaluate energy system resilience under heating electrification. While PV systems alone cannot stabilize winter grids, they can support voltage regulation through reactive power injection. CHP units proved especially effective in managing winter loads, and grid reinforcement remains costly but partially effective. The challenge lies in balancing these approaches and defining optimal control strategies for local conditions.

ECONOMIC FACTS & FIGURES

Investment requirements differ depending on the scenario. Grid reinforcement entails high capital expenditure, particularly in dense urban areas. CHP deployment involves moderate costs and delivers both thermal and electrical output, making it a cost-efficient solution when aligned with heat pump operation. Reactive power control via PV inverters offers a lower-cost option for voltage regulation but requires careful coordination. The simulation tool enables comparative assessment of these strategies from both a technical and economic perspective.

REPLICATION POTENTIAL IN SWITZERLAND

LESSONS LEARNED:

- The combined effect of HP adoption and winter electricity demand stresses voltage and line capacity limits.
- CHP units offer dual benefits: they meet heat demand and generate electricity at exactly the right time, stabilizing the grid more effectively than PV or reinforcement alone.
- PV installations alone have little winter impact, though reactive power support can help mitigate under-voltage; however, when combined with reinforcement they still do not outperform CHP.
- Grid reinforcement is effective in addressing line congestion, but less so for voltage management.
- A universal approach is not viable — control strategies must be localized, based on the real-time condition of each subgrid and the location of PV installations.
- The modeling framework supports scenario testing at hourly resolution and provides spatial insights (e.g., which lines or buses are most at risk).

The project confirms that decarbonizing urban heating systems requires not only sustainable technologies, but also a clear understanding of their system-level impact. The Python-based modeling approach developed by HEIG-VD offers a practical, transferable tool for municipalities and utilities to assess infrastructure needs, anticipate grid bottlenecks, and identify resilient transition strategies. By enabling precise, location-specific simulations, the methodology supports evidence-based planning for heating electrification in line with Switzerland’s energy and climate goals. ■

Project Example: Lake Energy Project – Steinach SG, Horn TG

PROJECT DESCRIPTION

The Lake Energy Project in Steinach (SG) and Horn (TG) supplies more than 110 residential, commercial, and industrial buildings with sustainable heating and cooling through a cold anergy network. Lake Constance water is extracted, cooled by around 3 °C in a central energy centre, and returned to the lake via a closed-loop system. A hydraulically separated secondary network distributes this energy to decentralized heat pumps installed directly in the buildings. Heating demand is met with just under 20% electricity, achieving a coefficient of performance (COP) above 5, while roughly 40% of buildings also benefit from free or active cooling.

Launched in 2023 by See Energie AG, with the municipality of Steinach as co-shareholder, the project was designed to reduce fossil fuel consumption, provide long-term price stability, and support local climate goals. Following a successful feasibility study, the company secured contracts for about 80% of the total capacity within its first year. With political backing from the municipalities of Steinach and Horn, and building on the proven technical maturity of similar projects in Switzerland (e.g. Seenergie Horw/Kriens, Würth Rorschach, Migros Arbon), the system demonstrates both environmental and economic advantages for a wide range of building types—from single-family homes to large industrial sites.

INVOLVED ACTORS

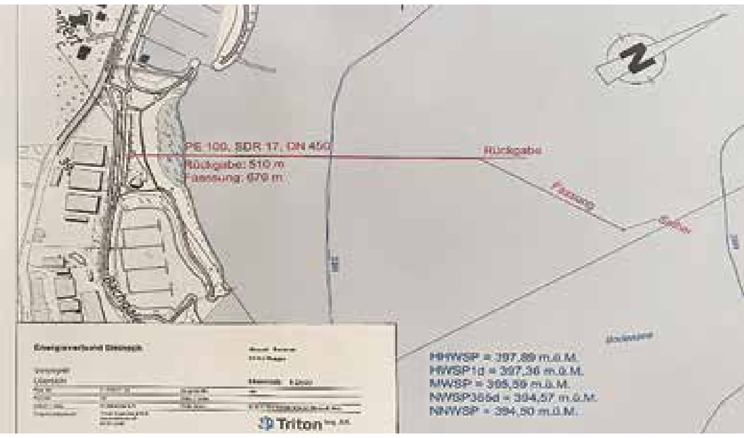
The idea of using Lake Constance water for energy supply in Steinach was first developed in 2023. Building on these foundations, See Energie AG was established as the dedicated project developer. The Municipality of Steinach and the Canton of St. Gallen supported the initiative with feasibility studies, both of which confirmed technical and economic viability. Today, the company is guided by its board and project management team, with around 80% of potential customers already committed through contracts for energy supply and free cooling.

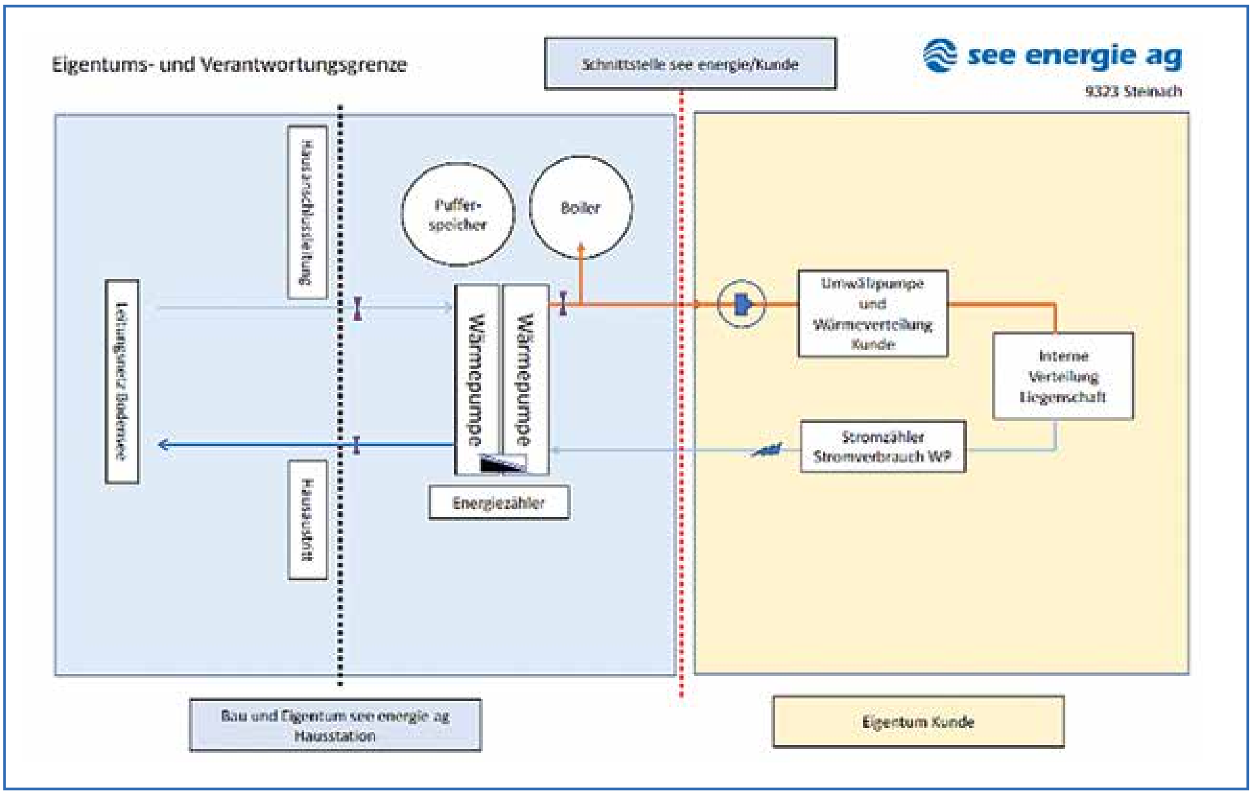
GOALS

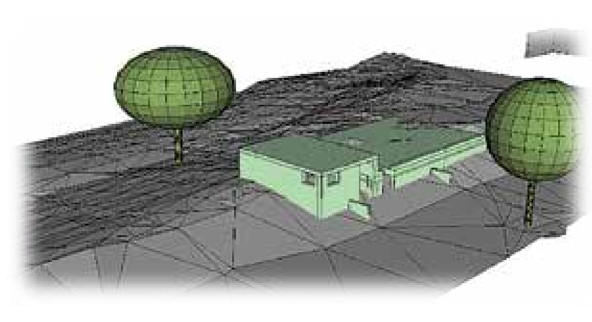
The project aims to reduce CO_2 emissions by using Lake Constance water as a local, renewable energy source for heating and cooling. A cold anergy network delivers energy to over 110 buildings, where decentralized water/water heat pumps achieve a seasonal efficiency above COP 5, with just under 20% electricity input. The system also enables free or active cooling in approximately 40% of connected properties. To support the 2050 climate targets and ensure long-term price stability, the project uses an integrated contracting model covering all installation and connection costs. Optional PV systems on buildings allow users to further reduce operational electricity demand.

STATUS & KEY FIGURES

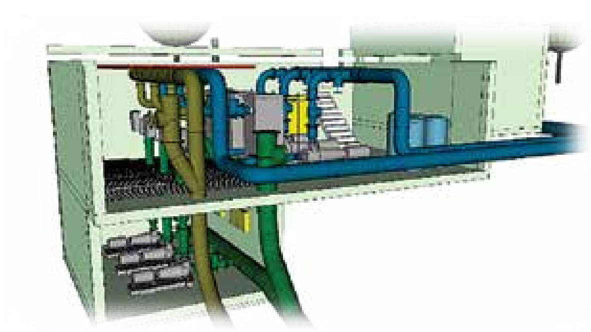
Implementation is ongoing, with around 10 heat pump systems already in operation. The network will eventually supply approx. 800 residential units across 110 buildings in Steinach and Horn, representing 0.2% of Lake Constance's theoretical thermal energy potential. The intake system includes a 670 m-long supply pipe and a 510 m-long return pipe, both submerged in the lake. The cold water network delivers energy at approx. 6–9 °C, and buildings return water at around 2.5 °C. With







Energiezentrale Aussen



Energiezentrale Innen

decentralized Hoval water/water heat pumps, the system achieves COP values above 5. Around 40% of properties also use free or active cooling. Local PV integration remains optional and is being explored to offset electricity use.

BENEFITS AND CHALLENGES

The successful contracting of over 110 properties across residential, commercial, and industrial use types highlights strong community interest. The main technical challenge has been routing the network through private plots, which often required individual negotiations and concessions. Installation in tight building spaces also proved more complex than with fossil systems. Regulatory uncertainty regarding the choice of fill medium (e.g. alcohol-free) and minimum system temperatures added complexity during planning. Overall, the project has proceeded without major technical barriers and is considered a success.

ECONOMIC FACTS & FIGURES

The total energy demand for the network is approx. 7 GWh/year, supplying ~800 residential units across 110 buildings, plus several commercial and industrial properties. This corresponds to just 0.2% of Lake Constance's theoretical thermal energy potential. Customers only pay the effective energy costs, as all infrastructure investments (heat pumps, connection, system integration) are included in the contract. The project achieves high efficiency with a COP >5, resulting in just ~20% electricity input. Additional cost savings can be realized via optional on-site PV installations.

Local governments are uniquely positioned to implement energy transition projects that serve both public and private stakeholders. The showcased initiatives demonstrate that technical feasibility is only one part of the equation—successful execution depends equally on governance structures, financing mechanisms, and social acceptance. To enable widespread replication, municipalities require supportive legal frameworks, planning certainty, and models for fair cost and benefit sharing. When these conditions are in place, municipal projects can become scalable blueprints for resilient, low-carbon communities.

REPLICATION POTENTIAL IN SWITZERLAND

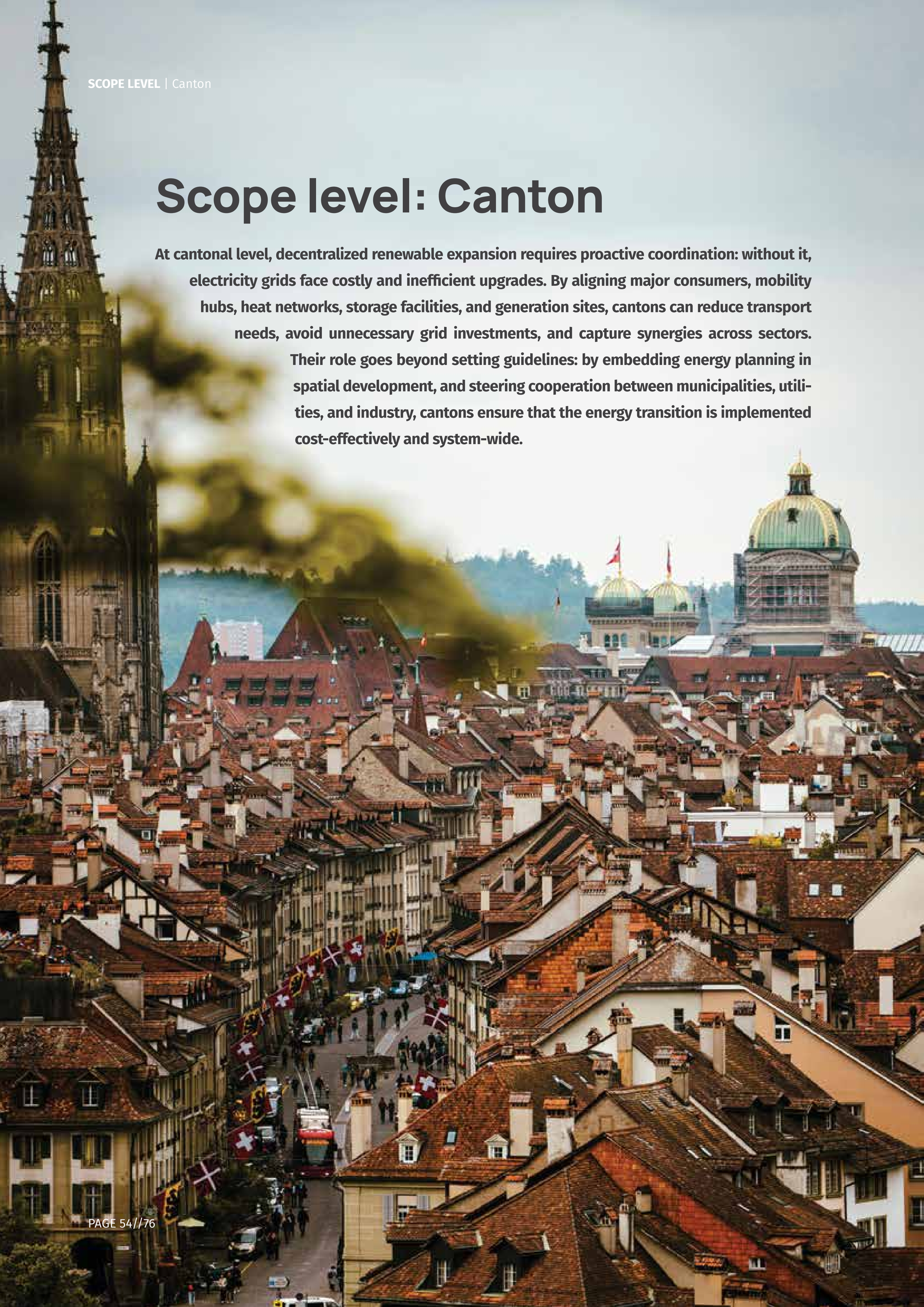
LESSONS LEARNED:

- Close collaboration with municipalities and residents is key for trust and participation.
- Routing the anergy network through private properties remains a major hurdle and requires proactive, case-by-case negotiation and concessions.
- A bundled contracting model (including heat pump, boiler, connection, and integration) simplifies the decision for end users and increases participation.
- Clear legal definitions around ownership boundaries (e.g. heat pump installed on third-party land) reduce misunderstandings and project risks.
- Early feasibility and technical studies ensured both technical soundness and scalability, with the later inclusion of Horn improving overall economics.
- Mixed building typologies—from single-family homes to large industrial sites—can be served effectively with one energy concept if properly planned.

The Lake Energy Project in Steinach and Horn demonstrates the high potential of cold anergy networks in lakeside municipalities. With over 110 buildings already contracted and a scalable, efficient system architecture in place, the model shows strong replicability. Strategic partnerships between local authorities and private investors, combined with an inclusive contracting approach, enable broader decarbonization at municipal level. ■

Scope level: Canton

At cantonal level, decentralized renewable expansion requires proactive coordination: without it, electricity grids face costly and inefficient upgrades. By aligning major consumers, mobility hubs, heat networks, storage facilities, and generation sites, cantons can reduce transport needs, avoid unnecessary grid investments, and capture synergies across sectors. Their role goes beyond setting guidelines: by embedding energy planning in spatial development, and steering cooperation between municipalities, utilities, and industry, cantons ensure that the energy transition is implemented cost-effectively and system-wide.



Project Example: Concept for Energy Infrastructure Expansion (KAEN)

PROJECT DESCRIPTION

The Canton of Bern is developing the Concept for Energy Infrastructure Expansion (Konzept Ausbau Energieinfrastrukturen - KAEN) to define how the targets of the cantonal energy strategy can be achieved by 2050. Building on the constitutional amendment adopted by voters in 2021, which set the course for climate neutrality by mid-century, the concept sets out how electricity and heat demand will be covered using renewable sources. It addresses not only production but also the distribution, storage, and use of electricity in a coordinated way. The aim is to integrate generation, transformation, and consumption into a coherent approach to sustainable energy supply. Central to the concept is the spatial designation of energy infrastructures and the identification of facilities with spatial relevance, so that corresponding provisions can be anchored in the cantonal structure plan.

INVOLVED ACTORS

The project is led by the Office for Environment and Energy of the Canton of Bern, supported by a project team comprising representatives from various cantonal departments. External stakeholders include industry associations, regional and municipal federations, as well as BKW as utility and grid operator. In addition, external mandates are awarded for tasks such as identifying potential areas and facility sites or conducting legal assessments. This broad involvement of administrative and external actors ensures that technical, regulatory, and spatial planning considerations are addressed in an integrated manner.

> “
>
> **TARGETED SECTOR COUPLING ALLOWS SYNERGIES THAT REDUCE THE NEED FOR GRID EXPANSION AND STORAGE CAPACITY, THEREBY LOWERING IMPORT DEPENDENCY AND GENERATION COSTS.**

GOALS

The KAEN concept defines how the Canton of Bern will coordinate renewable expansion and sector coupling up to 2050. Its main objectives are to:

- Define expansion pathways for renewable electricity toward 2035 and 2050.
- Designate suitable areas for large-scale facilities of cantonal or national importance.
- Identify major consumers and align them with production and infrastructure planning.
- Integrate storage and distribution solutions to strengthen supply security.
- Provide recommendations for updating the cantonal structure plan and strategies to move designated sites into concrete projects.

STATUS & KEY FIGURES

The project is in progress and will be published in draft form in winter 2025, after which it will be submitted to the cantonal government. Spatially relevant findings will be incorporated into the cantonal structure plan.

- Draft completion: winter 2025
- External expenditure: approx. CHF 50,000 (majority of work carried out by the canton)
- Methodology: based primarily on GIS analyses from cantonal databases and publicly available geodata
- Data basis: GIS analyses, Energy and Climate Data Platform, grid operator inputs
- Expansion targets: +4,500 GWh renewable electricity by 2035, +8,700 GWh by 2050 (vs. 2006 baseline)
- Main sources considered: hydropower, photovoltaics, wind power, biomass
- The concept illustrates where spatial potential exists to realize the targeted expansion cost-efficiently by 2050

BENEFITS AND CHALLENGES

KAEN gives the Canton of Bern a structured basis to coordinate renewable energy expansion across production, storage, and consumption. By designating areas for infrastructure and integrating them into the cantonal structure plan, the concept accelerates site identification, streamlines approval procedures, and creates certainty for investors and developers.

CHALLENGES

- Data collection requires inputs from numerous stakeholders and is resource-intensive.
- Complete coverage of all current and planned projects cannot realistically be achieved.
- The process relies on pragmatic assumptions and acceptance of information gaps.

ECONOMIC FACTS & FIGURES

The KAEN is developed primarily within the canton's own mandate, with external costs limited to around CHF 50,000. The analysis draws

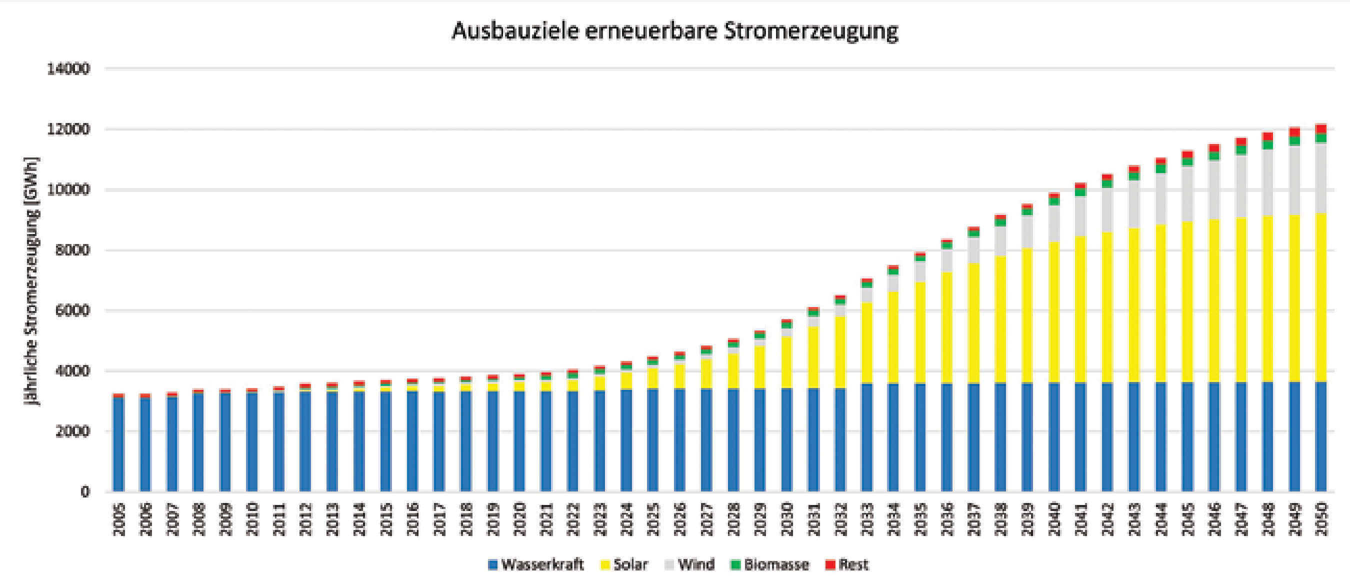
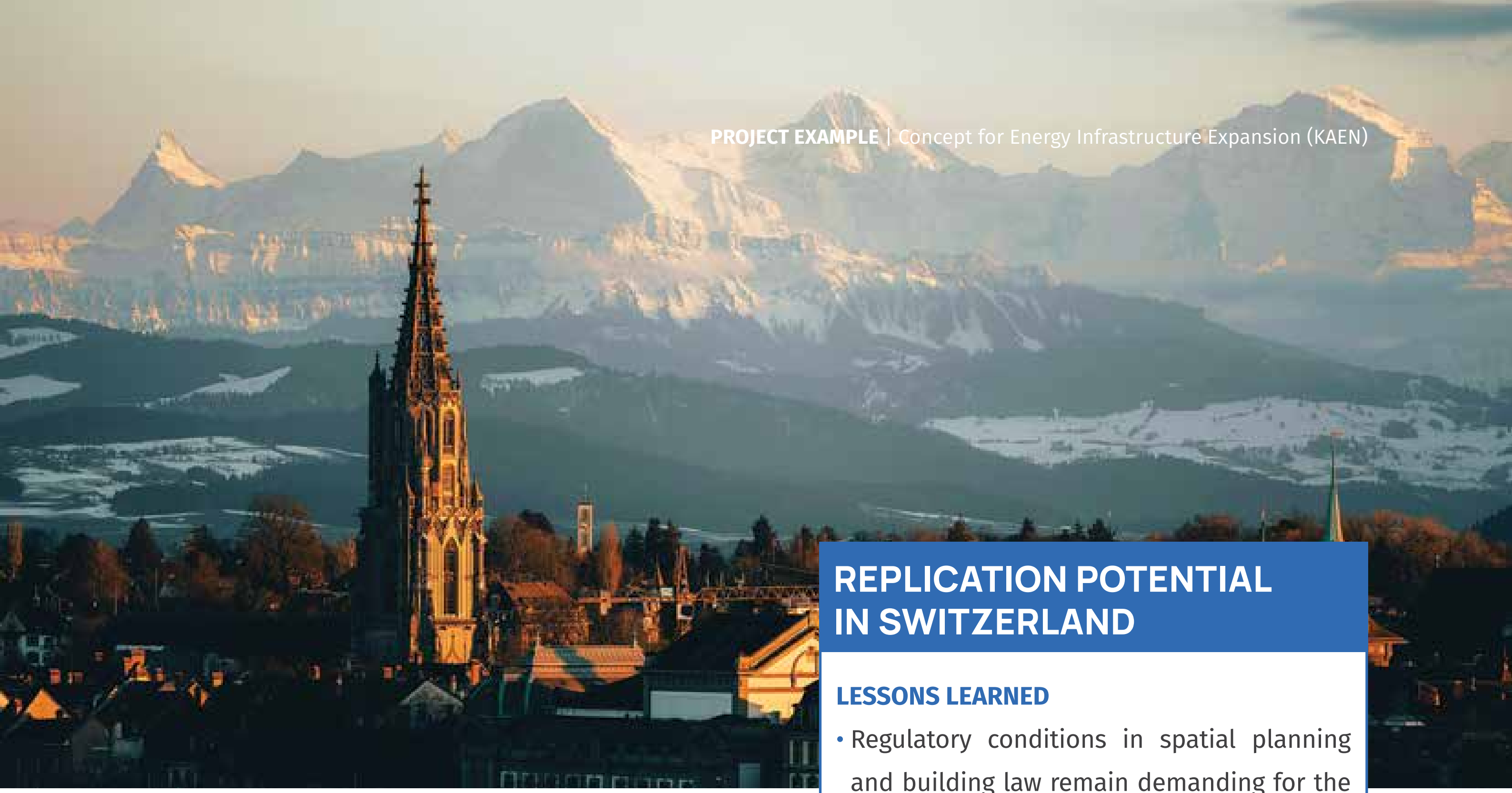


Diagram 1: Expansion targets for renewable electricity generation in accordance with the energy strategy



on GIS data, the cantonal Energy and Climate Data Platform, and inputs from grid operators. According to the energy strategy, renewable electricity generation in Bern must increase by about 4,500 GWh by 2035 and 8,700 GWh by 2050 compared with the 2006 baseline. The concept therefore sets specific expansion paths for hydropower, photovoltaics, wind power, and biomass as the main energy carriers.

Experience at cantonal level shows that the energy transition cannot succeed without spatial coordination and clear regulatory frameworks. Concepts like KAEN demonstrate how strategic planning can reduce approval hurdles, lower system costs, provide investors with greater certainty, and ensure that renewable expansion aligns with long-term climate goals. For Switzerland as a whole, this underlines the importance of cantons taking an active steering role: not by replacing local initiatives, but by linking them into a system-wide perspective that aligns generation, consumption, and infrastructure development.

REPLICATION POTENTIAL IN SWITZERLAND

LESSONS LEARNED

- Regulatory conditions in spatial planning and building law remain demanding for the expansion of renewables and sector coupling.
- For new technologies such as ground-mounted PV, electrolysers, e-mobility hubs, and hydrogen applications, both knowledge and regulations are still limited.
- The collection of all necessary information is complex and rarely exhaustive, requiring pragmatic approaches and acceptance of gaps (“Mut zur Lücke”).

The decentralized expansion of renewable energy in Switzerland could be better aligned with existing infrastructures and future demand through similar concepts at the cantonal level. Targeted sector coupling allows synergies that reduce the need for grid expansion and storage capacity, thereby lowering import dependency and generation costs. The KAEN thus provides an example of how cantons can assume a coordinating role in planning, regulation, and stakeholder involvement, helping to accelerate the energy transition in line with national climate targets.

Project Example: Climate Strategy Thun

PROJECT DESCRIPTION

In 2019, following a youth initiative, the city of Thun declared a climate emergency and committed to achieving net zero greenhouse gas emissions by 2050. The city administration itself set a more ambitious target of net zero by 2035. The municipal council tasked the Environment, Energy & Mobility office with developing a climate strategy, which was approved with a dedicated budget. The strategy was designed in a participatory process involving local businesses, experts, and citizens to ensure broad support. Sector coupling is not treated as an isolated measure, but as a strategic direction within the roadmap and embedded in the action plan. Key measures include a cluster analysis for heating system replacement, expanded support for energy efficiency and PV, demand-driven roll-out of EV charging, and the “Reallabor Thun”(Living Lab Thun) as an experimental platform to test cross-sectoral solutions.

INVOLVED ACTORS

The city of Thun leads the development and implementation through the Environment, Energy & Mobility office. Political oversight is provided by the municipal council and city parliament. External partners include local energy suppliers, planning offices, housing associations, universities, and engineering firms. Support is also provided through national programs (e.g., EnergieSchweiz) and the EU Horizon 2020 project 2ISECAP.

GOALS

The climate strategy provides a long-term roadmap and short- to medium-term action plan to:

- Achieve net zero emissions in Thun by 2050 (city administration by 2035).
- Embed sector coupling across energy, mobility, and buildings.
- Provide clear implementation steps, timelines, and monitoring.
- Ensure broad participation of local businesses, experts, and residents.

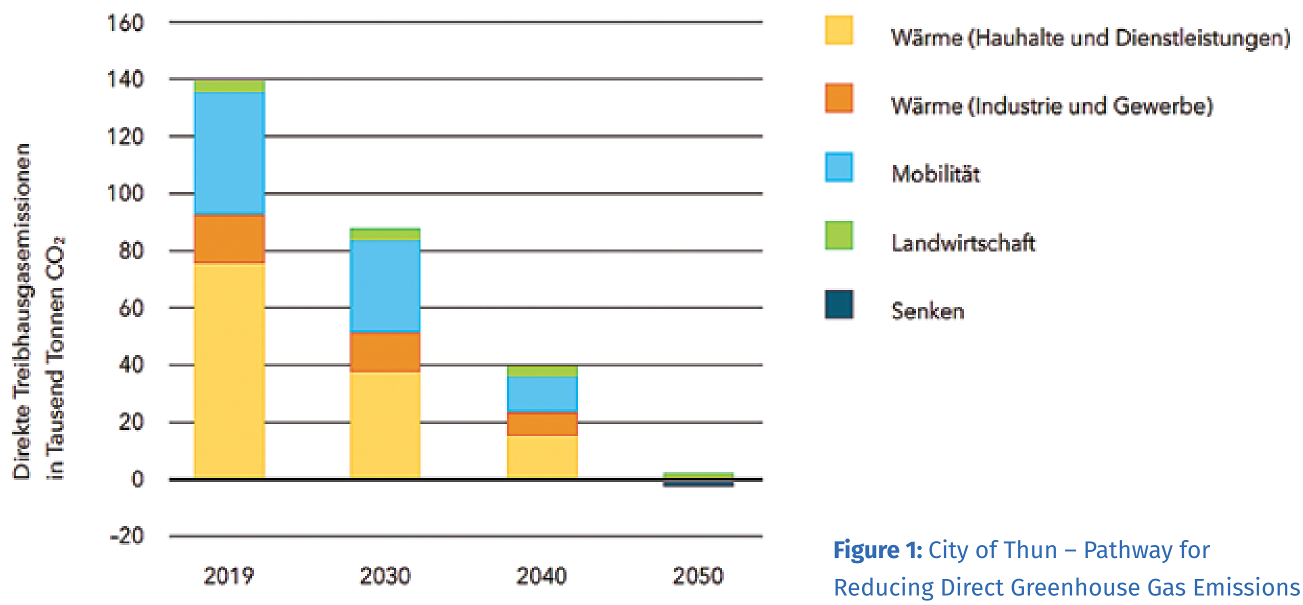


Figure 1: City of Thun – Pathway for Reducing Direct Greenhouse Gas Emissions

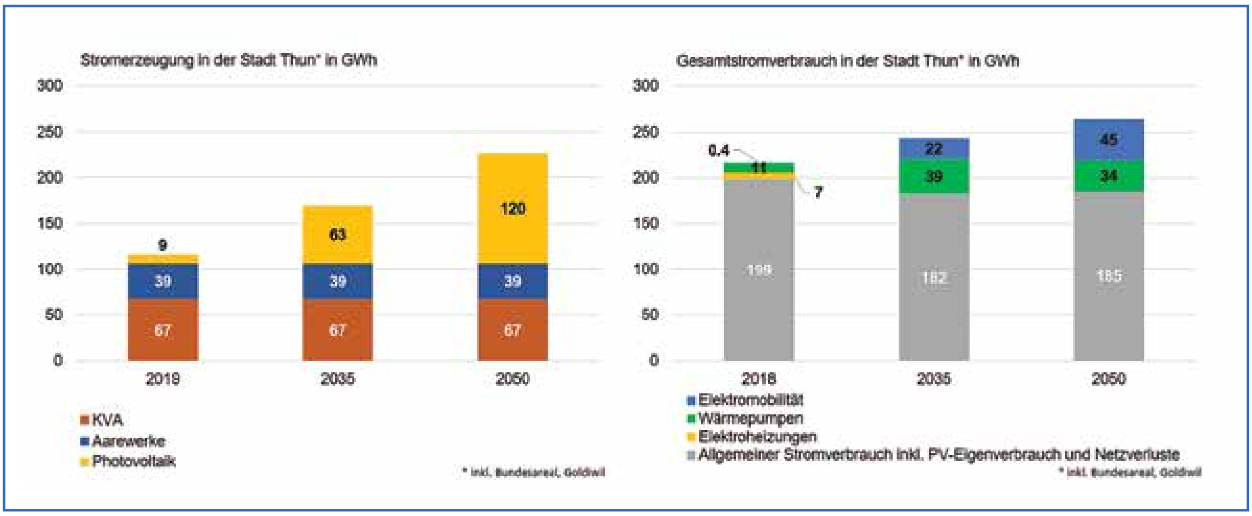
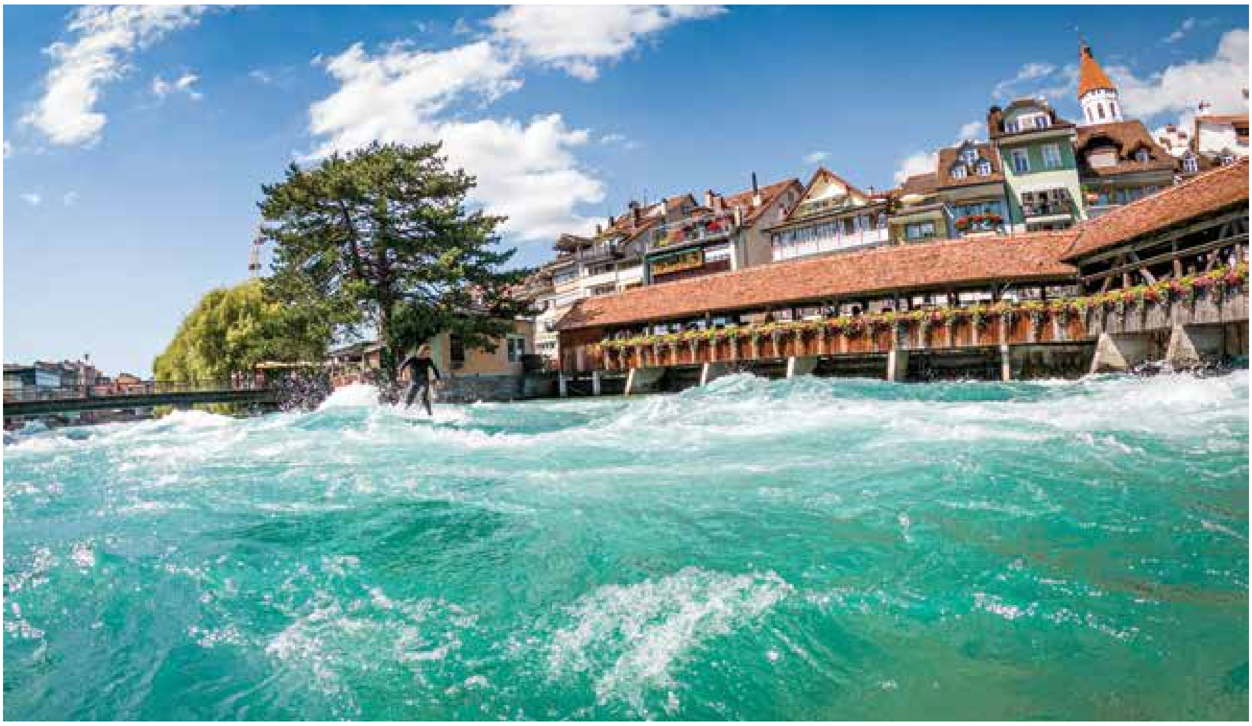


Figure 2: The long-term renewable energy potential (primarily solar power) indicates that, together with further efficiency improvements, electricity supply can become predominantly renewable by 2050.

STATUS & KEY FIGURES

The climate strategy is already operational, with the roadmap approved and the first measures from the action plan in implementation. Progress is tracked systematically to ensure transparency and alignment with long-term climate goals.

- Roadmap and action plan 2023–2026 adopted, with first measures underway
- Monitoring: interim reporting every 2 years, full assessment every 4 years
- Next action plan scheduled for 2027–2030
- Example measures: cluster analysis for heating, PV expansion, EV charging pilot, Thun Living Lab



BENEFITS AND CHALLENGES

The climate strategy brings together politics, administration, businesses, and citizens, ensuring broad legitimacy, local ownership, and stronger public acceptance. By embedding sector coupling both in the climate strategy and the Smart City vision, the city benefits from synergies across departments. Targeted funding enables pilot projects to move from vision to practice and increases overall implementation capacity.
Challenges remain, particularly in implementation:

- Limited internal administrative resources require external support from universities and engineering firms.
- Financing depends on targeted subsidies and early, coordinated planning.
- Implementation timelines are affected by complex approval processes and competing priorities within the administration.

> BY EMBEDDING CROSS-SECTOR MEASURES IN A STRATEGIC ROADMAP AND ACTION PLAN, MUNICIPALITIES CREATE THE BASIS FOR COORDINATED IMPLEMENTATION ACROSS ENERGY, MOBILITY, AND BUILDING SECTORS.

ECONOMIC FACTS & FIGURES

The city estimates costs for the 2023–2026 action plan at CHF 1.1–1.6 million, financed from the municipal budget and external contributions (EnergieSchweiz, EU Horizon 2020). Many measures generate indirect economic benefits by reducing energy demand, supporting renewable deployment, and stimulating local business activity.

REPLICATION POTENTIAL IN SWITZERLAND

LESSONS LEARNED

- Cross-sectoral integration works best when climate strategy and Smart City planning are aligned.
- Strong participation across politics, administration, business, and citizens increases acceptance and impact.
- External support relieves administrative burden and improves project quality.
- Early financial planning and access to subsidies are crucial for turning strategy into action.
- Medium-sized cities can play a pioneering role if sector coupling is embedded strategically and operationalized through concrete, phased action plans.

Thun demonstrates that sector coupling can be anchored effectively in municipal climate strategies and pursued in a structured manner. By embedding cross-sector measures in a strategic roadmap and action plan, municipalities create the basis for coordinated implementation across energy, mobility, and building sectors. The Thun approach highlights the importance of early stakeholder alignment, regulatory clarity, and dedicated resources, offering a transferable model for other Swiss cities and towns seeking to accelerate their path to net zero.

Scope level: Region

Regional initiatives demonstrate how complementary renewable sources, intelligent system operation, and applied experimentation contribute to building resilient energy systems ahead of large-scale deployment. Rather than highlighting individual technologies, the focus lies on the interaction of different sources, the integration of flexibility, and the ability to derive practical insights from real-world operation.

The Swiss Energypark – a miniature version of Switzerland in 2050

DESCRIPTION

What makes the Swiss Energypark unique is not a spectacular technology, but the intelligence of a territory. Here, emblematic installations — the Goule dam, the Mont-Soleil photovoltaic plant (Europe's largest when it was commissioned in 1992), and Switzerland's largest wind farm — were established long before the term "energy transition" became common. These early choices, carried by a population attached to its pioneering identity, made it possible to locally anchor a diverse and complementary renewable mix. On this remarkable foundation, the Swiss Energypark was created; it is a platform for experimentation, a place to explore, at grid scale, how to integrate renewable energies by leveraging flexibilities.

INVOLVED ACTORS

Located across the cantons of Bern and Jura, the Swiss Energypark brings together a variety of renewable electricity production that annually covers between 80 and 90% of the needs of the 23,000 inhabitants served by the network of the Société des Forces Électriques de la Goule. It all began with the initiative of a handful of visionary industrialists who harnessed hydropower from the Doubs to supply the watchmaking industry at the end of the 19th century. A century later, in 1992, Europe's largest photovoltaic plant was built, while the sector was still in its infancy. The aim of this project was to demonstrate the reliability of this technology in practice. The original plant is still in place, and monitoring shows a degradation of only 7.5% in its performance over 33 years. By the late 1990s, Juvent installed a wind farm made up of 16 turbines which — after two repowerings — reached a nominal capacity of more than 37 MW, i.e. more than half of national wind production. Finally, in the early 2010s, smart meters were installed for all customers served by the network.

In the coming years, the Swiss Energypark will host a major photovoltaic installation as part of the "Solar Express" initiative. It will add around 5 GWh of additional electricity during the winter season.

With such local renewable production, the Swiss Energypark is a miniature version of Switzerland in 2050. It is naturally a pilot region that makes it possible to observe the complementarity of different renewable sources.

GOALS

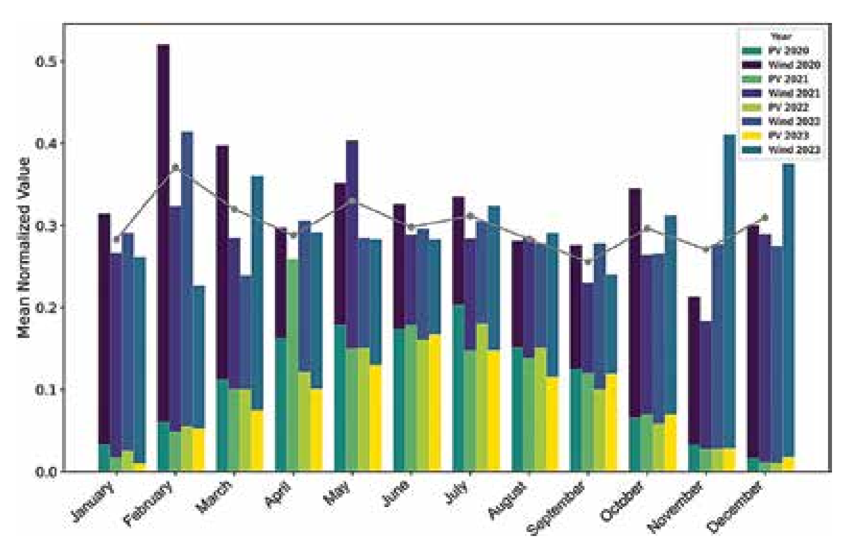
One of the major challenges, however, remains matching production and consumption in real time. This is where the complementarity of the mix plays an essential role, as it allows a significant increase in direct self-consumption. This dynamic, at the heart of the Swiss Energypark, is fully aligned with reflections on flexibility and sector coupling.

The Swiss Energypark also offers a unique opportunity to test innovative solutions in the field of energy flexibility, anchoring the transition in real-world experience. The research projects take different forms:

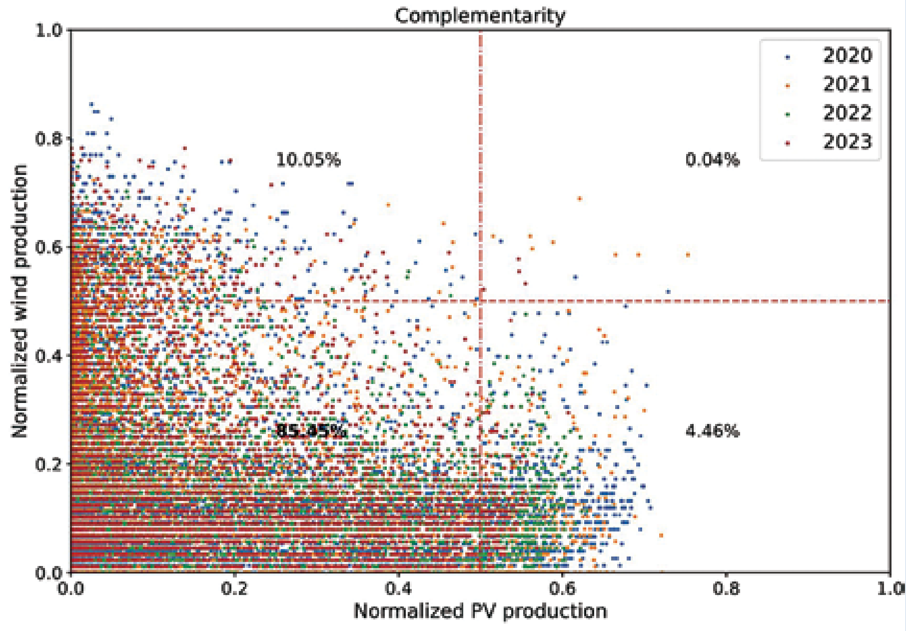
- Physical, such as the CircuBAT project
- Digital, with the Swiss Energypark having developed its own digital twin
- Behavioural, such as the InfiNeed 2 project

KEY FIGURES

The graphs below show normalized photovoltaic and wind production between 2020 and 2023 at the Swiss level. The first illustrates a marked trend: solar production reaches its maximum in summer, while wind is stronger in winter, reinforcing their seasonal complementarity. It confirms an intuitive perception that winter photovoltaic output is naturally lower than in summer. However, the second graph, based on more than 35,000 hourly data points, shows that in 85.45% of cases at least one of the two sources is active, limiting situations of double absence. Conversely, simultaneous production close to theoretical maxima occurs only 0.04% of the time, which considerably reduces the risk of grid congestion. This study clearly demonstrates a strong complementarity also at the hourly level.



Graph 1: Monthly correlations between solar PV and wind generation for 2020–2023.
Source: Energy reports (June 2025): «Embracing wind power in the solar PV-dominated Swiss landscape».



Graph 2: Hourly correlations between solar PV and wind generation for all years together (2020–2023).
Source: Energy reports (Juen 2025): «Embracing wind power in the solar PV-dominated Swiss landscape».

> THE SWISS ENERGYPARK ALSO OFFERS A UNIQUE OPPORTUNITY TO TEST INNOVATIVE SOLUTIONS IN THE FIELD OF ENERGY FLEXIBILITY, ANCHORING THE TRANSITION IN REAL-WORLD EXPERIENCES.

REPLICATION POTENTIAL IN SWITZERLAND

The analysis shows that a 100% solar or 100% wind system would require large storage capacities to ensure balance. By contrast, a well-calibrated mix cuts these needs in half. What makes this configuration valuable for sector coupling is that it acts as a natural buffer. The complementarity of sources smooths variations and limits the need for backup equipment or massive reserves. This avoids major expenses on heavy infrastructure, redundant storage, or imports.

In this way, the Swiss Energypark does not address the limits of an existing system; it anticipates a desired future situation. It provides a real-world demonstration of what a territory could look like where complementarity itself constitutes a form of structural sector coupling.

The Swiss Energypark demonstrates that a territory can embody, ahead of time, the principles of a resilient energy system. Three key points emerge:

- A complementary energy mix that acts as a structural stabilizer for the grid
- Local experimentation that anticipates balancing levers and increases acceptability
- A grid that becomes not a bottleneck, but a living, accessible platform for innovation.

Scope level: National

At national level, sector coupling is essential to balance Switzerland's energy system across seasons. Power-to-X technologies link electricity with gas, heat, and industry, offering both storage capacity and flexibility. By converting surplus renewable electricity into synthetic fuels and integrating them into existing infrastructures, such projects help bridge the winter supply gap, reduce CO_2 emissions, and diversify system resilience. The GreenGas project in Aigle illustrates how Switzerland can develop a scalable pathway toward carbon-neutral gas.

Figure 1 Control & Surveillance Centre (CSA) in Aigle (VD)

Project Example: GreenGas

PROJECT DESCRIPTION

The GreenGas project is Gaznat's power-to-X showcase at its Control & Surveillance Centre (CSA) in Aigle. A 487 kWp rooftop PV array powers a 0.5 MW alkaline electrolyser, which produces hydrogen. This reacts with locally captured CO_2 in a 225 kWth methanation reactor to yield grid-quality synthetic methane. The system achieves >99% single-pass conversion efficiency, while waste heat is recovered to cover more than half of the building's demand. Hydrogen and liquid CO_2 are stored on site, and the facility is directly connected to the high-pressure gas grid. Conceived in 2018 with EPFL and GRZ Technologies, the plant was commissioned in 2023 and now functions as an open "Innovation Lab."

INVOLVED ACTORS

The project is owned and operated by Gaznat SA, the gas transmission operator for Western Switzerland. Key partners include EPFL (Laboratory of Materials for Renewable Energy and Laboratory for Advanced Separations), GRZ Technologies, Green Hydrogen Systems, Planair, OIKEN, and several EPC contractors. Public support was provided by the Swiss Federal Office of Energy, the Canton of Vaud, and the Swiss Gas Industry R&D fund (administered by the association of the Swiss gas industry VSG, today operating under the brand Gazenergie).

GOALS

The GreenGas project pursues multiple objectives:

- Demonstrate a closed-loop power-to-gas system using local renewables and captured CO_2.
- Decarbonise operations of Gaznat's CSA site.
- Derisk methanation and graphene-membrane CO_2 capture for future commercial roll-out.
- Provide an open platform for R&D, innovation, and public engagement.

STATUS & KEY FIGURES

Since its commissioning in August 2023, the GreenGas facility has operated as a pilot-scale showcase for power-to-gas in Switzerland. With CHF 5.8 million invested—including federal, cantonal, and industry contributions—the site delivers measurable performance data that inform future scale-up.

- 487 kWp PV array (1,219 panels) powering a 0.5 MW electrolyser
- Hydrogen output: ~195 kg/day
- Methanation reactor: 225 kWth, ≈2 GWh synthetic methane annually, >99% single-pass efficiency
- Reactor efficiency: 83% (LHV); electrolyser utilisation >4,000 h/year
- Waste heat recovery: >50% of building demand
- CO_2 capture: 10 kg/day with a roadmap to 45 kg/hour
- Avoided emissions: ≈600 t CO_2/year

BENEFITS AND CHALLENGES

The GreenGas plant demonstrates the first Swiss integration of PV, hydrogen, CO_2 capture, and gas grid injection within one modular facility. It offers a high level of heat integration and functions as a living lab for startups and research.

Challenges remain in scaling and regulation:

- Seasonal mismatch, with winter PV shortfalls.
- CO_2 membrane and catalysts still at pilot scale and costly.

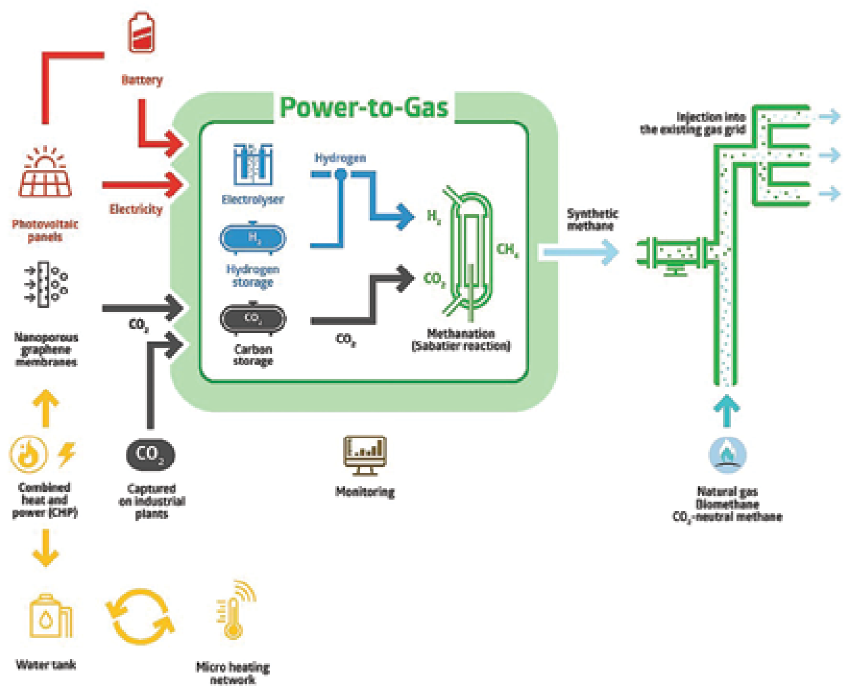


Figure 2 Schematic diagram of the GreenGas concept with its central Power-to-Gas installation

- Complex permitting requirements across multiple regimes (ATEX, PED, gas quality).
- Existing blending rules limit the share of synthetic CH_4 in the grid.

ECONOMIC FACTS & FIGURES:

The GreenGas project required a total investment of around CHF 5.8 million, financed through a mix of federal, cantonal, and industry grants. Operating costs are dominated by electricity and service expenditures, with the pilot targeting production costs of under CHF 0.12 per kilowatt-hour of synthetic methane. The levelised cost of electricity from the rooftop PV installation is estimated at roughly CHF 0.07/kWh, while the synthetic methane itself is expected to reach a cost range of CHF 0.12–0.15/kWh in the current set-up. With further scaling, costs could fall below CHF 0.09/kWh by 2030. At present utilisation levels, amortisation is projected at 12 to 15 years. As a demonstration site, the business case is primarily research-oriented, with future commercial value anticipated from negative-emission fuels and the provision of ancillary grid services.

National-level initiatives show that Switzerland's energy transition depends on frameworks that integrate technologies across sectors while ensuring economic viability and security of supply. By aligning regulation, infrastructure, and market signals, the national scope provides the foundation on which cantonal and regional efforts can scale, ensuring that local innovations contribute to a resilient and coherent energy system.

REPLICATION POTENTIAL IN SWITZERLAND

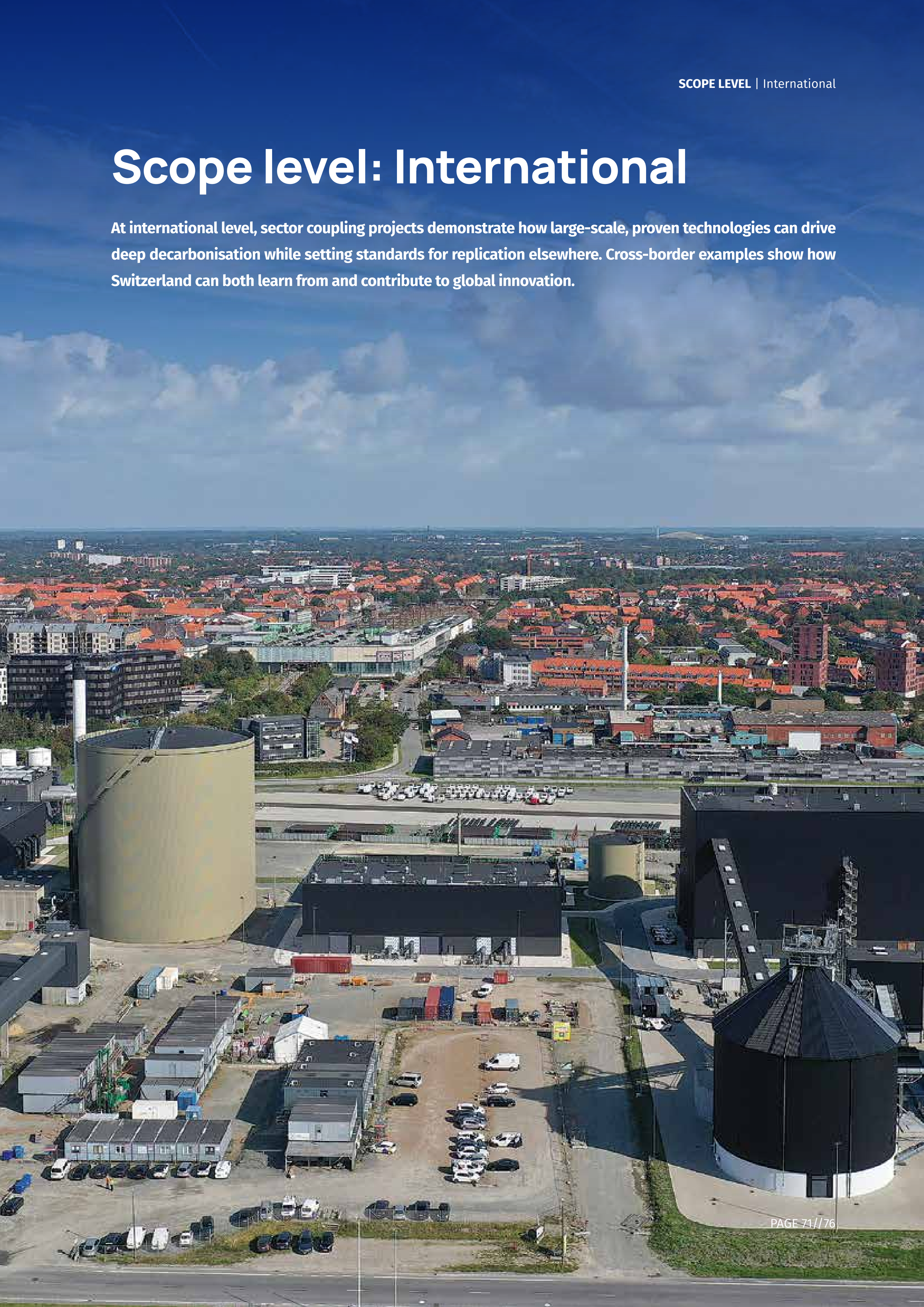
LESSONS LEARNED

- Containerised 0.5 MW PtG units can be placed on existing metering sites without major civil works.
- Using small hydride-based H_2 buffers proved more cost-effective than oversizing the electrolyser.
- Single-pass methanation achieves >99 % efficiency, with recovered heat covering ~50 % of building demand.
- Graphene CO_2 membranes and Ru catalysts work well but remain costly and pilot-scale.
- Permitting is fragmented (ATEX, PED, gas quality), underscoring the need for a single PtX route.
- An open “Innovation Lab” accelerates R&D and public acceptance.

The GreenGas model shows how power-to-gas can be embedded in existing infrastructure with strong national relevance. Deploying similar units at Gaznat's 15 stations could replace ~0.3 TWh of fossil gas and cut 80,000 t CO_2 annually. A 1 GW PtG fleet would meet ~20 % of winter gas demand, reduce 1 Mt CO_2 each year, and provide 500 MW of flexible demand. Scaling requires long-term renewable PPAs or direct-wire supply, reliable CO_2 streams, and a one-stop approval process. Green-gas blending quotas, CAPEX support via grants or CfDs, and industrial-scale membrane and catalyst production would further reduce costs and accelerate roll-out. ■

Scope level: International

At international level, sector coupling projects demonstrate how large-scale, proven technologies can drive deep decarbonisation while setting standards for replication elsewhere. Cross-border examples show how Switzerland can both learn from and contribute to global innovation.



Project Example: Mega Heat Pumps - Esbjerg, Denmark

PROJECT DESCRIPTION

In Esbjerg, Denmark, two 35 MW CO_2 mega heat pumps were commissioned in December 2024 to decarbonise the city's district heating. Using seawater in winter at just 1–3 °C as the heat source, the pumps replace part of a decommissioned coal-fired plant and now supply over 25,000 households or 100,000 people respectively with renewable heat. Supported by a 25,000 MWh thermal storage tank and a biomass plant, the system integrates into the wider energy network and provides both heat and grid-balancing services. The project, realised by the local utility operator DIN Forsyning in partnership with Everllence Switzerland (formerly MAN Energy Solutions), represents the world's largest operating CO_2 heat pump installation, using a seawater intake of 4,000 litres per second as its primary heat source.

INVOLVED ACTORS

The project is driven by DIN Forsyning, Esbjerg's local utility, which owns and operates the installation. Everllence Switzerland supplied the entire turnkey mega heat pump system including the HOFIM® compressors as core technology, ensuring both innovation and reliability. The initiative was further enabled by Danish policy support for coal phase-out and by local engineering and construction partners, making it a flagship example of international and cross-sector collaboration.

GOALS

The Esbjerg installation was conceived not only to phase out coal-based heat but also to serve as a lighthouse project demonstrating how mega heat pumps can anchor the energy transition at city scale. Its objectives span both local impact and international demonstration value:

- Deliver renewable district heating at full city scale.
- Demonstrate the technical and economic viability of CO_2-based mega heat pumps.
- Enable sector coupling by linking electricity, heating, and storage infrastructure.
- Provide system flexibility through grid-balancing services and thermal storage.
- Establish a replicable international benchmark for large-scale heat decarbonisation.
- New sector coupling plans are for cooling a nearby Data Center and a hydrogen production plant

STATUS & KEY FIGURES

Since their commissioning in December 2024, the two Esbjerg CO_2 mega-heat pumps have operated as a large-scale demonstration of district heating decarbonisation in Europe. The project delivers measurable system benefits in terms of CO_2 reduction, grid flexibility, and thermal efficiency.

- Installed capacity: 2 × 35 MW CO_2 heat pumps
- Heat supply: >25,000 households / 100,000 people via district heating
- Thermal storage: 25,000 MWh tank (1–3 days supply)
- Supplementary source: biomass CHP integration
- COP efficiency: ~3.1 using seawater in winter (1–3 °C) as heat source; >4.0 in summer (16-18°C)
- CO_2 savings: >100,000 t/year vs. coal-fired generation
- Key component: Two Swiss-made HOFIM® compressors (11 MW each)

© DIN Forsyning / Christer Holte

- In operation since Q4 2024
- Grid-balancing services supported by 25,000 MWh storage, with remuneration from the grid operator
- Future integration planned with a nearby Data Center and 1 GW hydrogen electrolysers for sector coupling

BENEFITS AND CHALLENGES

The Esbjerg project illustrates how mega heat pumps can anchor decarbonised urban heating while providing flexibility to the power system. It combines seawater heat extraction, renewable electricity use, and thermal storage into a fully integrated system, creating a blueprint for sector coupling at city scale.

CHALLENGES

- High upfront CAPEX and long planning horizons for district heating.
- Industrial users expect shorter ROI (3–5 years) than current 5–10 years.
- Electricity-to-gas price gap slows wider rollout compared to fossil alternatives.
- Knowledge and trust gaps remain significant across customers, investors, policymakers, and even parts of the expert community.

ECONOMIC FACTS & FIGURES

CAPEX for large-scale CO_2 heat pumps is currently estimated at CHF 600,000–700,000 per MWth, depending on source temperatures, storage integration, and site constraints. While amortisation of 5–10 years is typical for district heating, the system lifetime of 30–35 years ensures long-term cost competitiveness. With thermal storage and arbitrage capabilities, further OPEX savings are expected, particularly under dynamic power pricing.

International projects highlight how large-scale technologies can reshape entire energy systems. The Esbjerg installation shows that mega-heat pumps are capable of decarbonising urban heat supply while also delivering storage and grid-balancing functions. Such lighthouse projects set benchmarks for system transformation, offering a clear blueprint for adoption in other countries.

REPLICATION POTENTIAL IN SWITZERLAND

LESSONS LEARNED

- Mega heat pumps are technically mature and can replace fossil-fired district heating at city scale.
- Thermal storage is essential for system flexibility, grid-balancing and cost optimisation.
- Integration with other sectors (biomass, hydrogen, data centres) enhances economics and resilience.
- “Think Big” proved critical — larger capacity and storage would have improved economics further.
- Swiss-made technology (HOFIM® compressor system..) underpins the system, underscoring the export potential of Swiss innovation.

The Esbjerg project demonstrates that CO_2 mega-heat pumps are not only feasible but also replicable in Swiss cities with district heating networks. Applying similar systems could replace fossil-based urban heating, save hundreds of thousands of tonnes of CO_2 annually, and deliver flexible demand to the electricity grid. Switzerland’s technology base, regulatory support, and district heating expansion plans provide strong conditions to replicate and scale such projects domestically. ■

Conclusion

This whitepaper is not based on ideology, but on facts, projects, and experience. The evidence is clear: technologies exist, frameworks are evolving, and public support for decarbonization is strong. What is required now is decisive action.

As former Norwegian Prime Minister Gro Harlem Brundtland once observed:
“Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs.”

The energy transition embodies that responsibility. Switzerland has the capacity, the talent, and the will to act. By investing in innovation, enabling sector coupling, and fostering collaboration across all levels of society, we can secure affordable energy, protect our climate, and strengthen our economy.

The path forward is not without cost, but the cost of inaction will be far greater. If we act all together, i.e. citizens, businesses, researchers, investors, and authorities, we can turn today’s greatest challenge into an opportunity that defines Switzerland’s future.

The task before us is urgent, but it is also achievable. Let us seize this moment, and deliver a sustainable, regenerative energy system for the generations to come.
Let’s move together!

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